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THE SCIENTIFIC EXPERT IN FORENSIC PROCEDURE.

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[*A lecture delivered before the Franklin Institute, February 10, 1893.*]

The lecturer was introduced by the Secretary of the Institute, and spoke as follows:

MEMBERS OF THE INSTITUTE, LADIES AND GENTLEMEN:

The position and character of the representative of science in our courts of justice, always one of the greatest interest to those most directly affected, is acquiring every day a more general interest as the enterprise of the daily newspapers spreads before the public, often with comment, full reports of trials, in which, with increasing frequency, he often has a conspicuous part. A few years ago the appointment of a committee of the American Association

for the Advancement of Science was suggested to consider the whole subject, but no report appears among its proceedings. Among the announcements of congresses at the coming Columbian Exposition, is one of Medical Jurists. As members of the medical profession were the first formally recognized as scientific experts by imperial decree, and as they have broken the way by the rulings and precedents established, for other classes of scientific experts, it may seem fitting that they should continue to lead, but in view of the growing importance and peculiar features of science in this regard, it is almost a matter of regret that the subject for consideration of such a conference had not been made Forensic Science instead of Forensic Medicine, especially since the presence of experts of different nationalities, and under different systems of jurisprudence might have added much to the interest and value of the deliberations.

The more immediate suggestion of the subject for the lecture of this evening is due to a lecture upon the same subject by an eminent jurist of the State to the students of the law school of the institution with which I happen to be connected. Whilst, with all the freedom of the lecture platform, it abounded in instructive suggestions of the highest practical utility, originating largely in his own experience, and whilst it was courteous and even fair to the expert, it still had much of the coloring that the opinions of most of his profession of the expert have, and which at times finds expression from the bench as well as from the bar, and finds its way into reports and text-books, and which, in the case alluded to, seemed to make the burden of advice to the young lawyer—to watch carefully the scientific expert. As illustrative of this coloring, the following extracts have been collated from a great mass, not altogether at random, but as exhibiting different points of view, and the most salient points of animadversion upon the expert. They will serve, in a measure, to direct the discussion of the subject.

In *Taylor on Evidence* we find: "Perhaps the testimony which least deserves credit with a jury is that of skilled

witnesses. It is often surprising to see with what facility, and to what an extent their views can be made to correspond with the wishes or the interests of the parties who call them." "They do not, indeed, wilfully misrepresent what they think, but their judgment becomes so warped by regarding the subject in one point of view, that, even when conscientiously disposed they are incapable of expressing a candid opinion. To adopt the opinion of Lord Campbell they come with such bias upon their minds to support the cause in which they are embarked, that hardly any weight should be given to their evidence." A judge in a patent case, in his charge to a jury, says: "In a case of this kind the opinions of witnesses who are experts are admitted, contrary to the general rule, which requires witnesses to testify only to facts. And I must say, gentlemen, so far as my experience extends, that it would be as well if not better that the opinions of such witnesses should be excluded from the consideration of the jury." "They are selected on account of their ability to express a favorable opinion, which, there is great reason to believe, is in many instances the result alone of employment, and the bias arising out of it." In another charge to a jury we find: "It must be painfully evident to every practitioner, that these witnesses are generally adroit advocates of the theory upon which the party calling them relies. Even men of the highest character and integrity are apt to be prejudiced in favor of the party by whom they are employed." As to the effect of testimony of experts it is described, "as often as skilful and effective in producing obscurity as in elucidating truth." Again, a judge off the bench, in the greater freedom of a lecture, remarks: "From the proposition that experts alone may give their opinions upon the witness stand, that these opinions are admitted as such, and that the expert is to form and express his private conclusion upon the facts which the jury is summoned to try, from these propositions, it is but a short step to the full-blown expert, as we see him in actual operation, as one who being neither judge, nor juror, nor witness, nor advocate, exercises the privileges of them all, restrained by the limitations of

none." Another very clear writer upon this subject, makes the following statements: "Text-books and reports, when discussing what may be termed the testimony of experts, more accurately than expert testimony, will be frequently found to censure, and seldom to commend its practical administration; and, indeed, the unprofessional mind, in view of the general tenor of the expression of the authorities, finds it difficult to understand, why a system which would seem to be regarded as rather pernicious than beneficial, should be even tolerated by the law;" and, in another connection, "an examination, even though superficial, of the subject of skilled evidence, from whatever point of view it may be made, will not fail to indicate the liability in the operation of the system, to misapplication and perversion of its functions, though administered under rules which have been well considered, and enforced with a reasonable degree of strictness;" "though the law theoretically provides so high a standard of qualifications for the expert as might be presumed to insure his sufficient skill, and further enables his ignorance to be indicated, or his errors refuted, by cross-examination and controverting testimony, yet the inability of men in general to investigate without assistance the questions which the expert deals with, embarrasses the process of detecting his unfitness in the first instance, and of counteracting the obscurity or false impressions produced by his testimony if erroneous;" "the salient objection which presents itself in the application of skilled evidence, and one which is of necessity peculiar to the system, is the effort frequently made, with more or less success, to expand and pervert the functions of an expert * * * to the statement or discussion of questions of moral or municipal law." This arises, however, as he admits, from the circumstance that: "Law and fact in a certain class of cases [viz: patent cases], are frequently so closely blended that it may be difficult to clearly draw the line between them, and to determine where the province of the witness ends and that of the court begins." Another phase of objection is exhibited by Justice Miller, in a charge, as follows: "My own experience, both in local courts and

in the Supreme Court of the United States, is, that when the matter in contest involves an immense sum in value, there is no difficulty in introducing any amount of expert testimony on either side." Another judge, in a lecture upon "Medical Expertism," gives a similar opinion, that the grounds of dissatisfaction in regard to medical testimony, to both the professions of law and medicine, are "reducible to one, that upon every conceivable issue expert opinions are procurable, which sustain or seem to sustain the most contradictory views." These extracts, which might be multiplied indefinitely, exhibit a rather pessimistic view of the scientific expert, and one which, in our opinion, is hardly justified by a full consideration of all the facts, and which certainly is not just, in as far as it may imply censure of him, when we consider his relation to the system of jurisprudence, into which he has been thrust with little more responsibility on his part than he has for being born.

The scientific expert is simply a product, and an extreme product, of an advanced and rapidly advancing civilization. He was recognized in the germ, to be sure, by the old Roman law, and we may assume in all systems of jurisprudence; but he has acquired an immensely increased importance, and a much wider field and a far greater frequency of employment by the recent, and very recent, marvellous advances in the applications of science—applications which have increased the sphere of things to be litigated about, which have introduced facts of an entirely new character to be adjudicated upon, to say nothing of the contribution that science has made, and is continually making, in many ordinary cases, of conclusive missing links of evidence which render decision previously uncertain, comfortably certain, and satisfactory.

Now, one fact that seems latent in these expressions of the legal profession in regard to the scientific expert, and almost the first that impresses is that in many respects he seems to be a positive annoyance to lawyers, and even to judges at times—a sort of intractable, incompatible, inharmonious factor, disturbing the otherwise smooth current of legal procedure; too important or necessary to be ruled out,

too intelligent and disciplined mentally to yield without reason to ordinary rules and regulations of the court, with which he may not be familiar, and, at the same time, possessing an undoubted influence with a jury, that it is difficult to restrict by the established rules and maxims of legal procedure.

Indeed it would seem that no class connected with the administration of justice is more frequently misunderstood, or abused, unless, perhaps, we may except the legal fraternity itself, for the latter are often, by the laity, accused of bold mendacity, unscrupulous methods, dishonest practices. And they sometimes even contribute to this popular impression by contradiction, or even abuse, and apparent mistrust of each other, even to a greater degree than scientific experts. And yet no one would hold the noble profession of the law less a necessity in the administration of justice, or consider it fairly represented by cases that may be regarded, if they exist at all, as glaring exceptions, pictures all the more grotesque for the background of professional character upon which they are cast. Now, there must be some way of accounting for such a community of reputation of lawyer and expert, widely separated as they are in position and function. The one has the advantage of a well-defined, clearly comprehended legal status, the result of centuries of judicial procedure; he is a growth, influenced by all the changing demands of progress in social conditions for centuries. Though there may not have been a time, when he was not in the germ, and always important, the attorney is now a fully developed agent in judicial procedure. The scientific expert, on the other hand, occupies an ill-defined, hardly recognized, variously comprehended, anomalous position, and of comparatively recent importance. He is, in fact, a comparatively recent introduction into the world of jurisprudence. He is in process of development and adaptation to his surroundings. He is being shaped and fashioned rather than finally fixed, and much of the misapprehension of him, and consequent abuse of him, may be due to his apparent, or real, want of compatibility with the fixed forms and maxims of jurisprudence

which have the force of axioms in legal practice. Still the two professions, although thus widely dissimilar, must have some similar phases that may account in some degree for identity of reputation alluded to. Both are engaged in the trials of causes between litigants, and litigants in most cases fully persuaded of their rights. The lawyer and the expert, each in his sphere, contributes to the final decision. The memory of litigants is apt to be more tenacious of wrongs done than of rights secured. The rights are his, as a matter of course, and the lawyer, or expert, who has aided in securing them has but performed a simple duty, and may be regarded as fully paid, perhaps over-paid, by the fee. But the defeated litigant is apt to remember longer the opposing attorney, as a man, perhaps, of feeble sense of justice, of great cunning, perhaps of great legal ability, but mainly as the chief instrument in defrauding him of his just rights, and the expert, if one be associated in the case, shares this unfavorable opinion. The lawyer's opinion of an expert may rest upon somewhat similar grounds. The expert, who at a critical point may have saved a doubtful case, may be regarded by the lawyer as having performed a simple, perhaps an imperative duty; whilst the one who may have caused the loss of a case, or foiled an attorney, will be apt to be remembered by him as well as by his client, as a typical scientific expert, briefly characterized in the address to the court. "May it please the court there are three kinds of liars—the common liar, the damned liar and the scientific expert."

Another occasion of ill-feeling between the two professions may lie in the ill-defined position of the expert in court. In legal procedure there are hazy, doubtful zones, where the rules of practice are difficult of application, in which, as has been said, the scientific expert appears as playing all parts, with the restrictions of none; and yet, as we will see, he is classified by his functions with those who are regarded rather as inferiors by attorneys—namely, the witness class, and there may be a sort of *ne sutor ultra crepidam* feeling toward him on the part of the attorney, when he seems to rise above his class.

But aside from these rather incidental and comparatively trivial circumstances, there must be others of more comprehensive and graver character, which shape the reputation of the scientific expert with the bar, the bench, and to some extent with the laity, in as far as it does not filter down to the latter from the two former. In looking for these a multitude of questions almost jostle each other. What is the scientific expert? Why is he in court at all with all his failings? When did he get in? How did he get in? What are his relations to the other factors in the administration of justice, to the court, to the attorney, to the jury, to the other witnesses, to the parties in the case, to the community of which he forms a part, to civil law, to ethical laws, to his own profession, and then, the final, all-important practical question. What is the best thing to be done with him? If we restrict our inquiry to the jury system, most of these questions will meet their answers in a study of the growth of that system from the simple juridical germ, latent in archaic customs that with the effect of law regulated to some degree the rule of the stronger in the interest of the community. Thus primarily the avenger of a private wrong knew no limit to his revenge except his own will and power. All progress in jurisprudence rested upon increased assumption of control over individual conduct in accordance with the social instincts of the race. The prescribed rule of civil conduct for the individual was always becoming more detailed in its commands of what society considered right, and of prohibitions of what it considered wrong, and society was always incurring increased responsibility for the determination of facts, of conduct, and application of the rules. Elaborate systems of jurisprudence grew up. Our savage legal ancestors were late in evolving a system. Long before they had placed any restraint upon the right of the stronger, the Mosaic code had made the great advance in its restraint, which we might almost term the equitable basis of all modern law, of "an eye for an eye, and a tooth for a tooth." But late as the English system is its origin is lost in obscurity. The often-quoted figure of Sir Matthew Hale, "more undiscoverable than the sources of the Nile," although

it may have lost its applicability, has not lost its expressiveness. But whether it is based on Anglo-Saxon usages, or whether almost wholly upon those of later date matters little. It is certainly a growth, a product of the creative power of the nation working slowly, and with evidences permeating it of the unquenched and unconquerable Anglo-Saxon spirit even under the grinding oppression of the Conquest.

Now in the organic world progress, development is from simple to more complex, by a process of differentiation. Low in the scale we find the animal without organs, without mouth, without stomach, without respiratory organs, without organs of sense; no eyes, no ears. A portion of food floats against it, it is enclosed and digested; the air is absorbed through its whole surface; the light may affect the whole surface; it is all mouth, all stomach, all lungs, perhaps all eyes. Any part performs all functions. It is regarded as low down in the scale of animal life. As we ascend the scale we find portions of the body set apart for specific functions by a process of differentiation. Organs of digestion, of respiration, of locomotion, organs of sense, eyes affected only by light, ears affected only by undulations of the air, all clearly defined, and as they perform their several functions, doing best only that which they are set apart to do, until we reach the culmination of development in highly differentiated and complex mammalian type. Thus the English system, by a process very analogous to differentiation, gradual, at times tedious and perhaps imperceptible, influenced by social and political changes, by the general progress in civilization, and following the same law that greater perfection demands greater complexity, to-day exhibits a sharply defined, legally constituted, fourfold division of juridical functions to four as clearly defined specialized organs of jurisprudence, each regarded as as incompetent to perform the functions of the other, as the eye to perform the functions of the ear, or the ear to perform those of the eye. We may not be able to trace the successive stages of development very clearly. What we regard as trial by jury in the Magna Charta may resemble it only in

its faintest outlines, as indeed it may resemble other systems in many of its features. It may possibly hardly suggest our present jury system. But it had in it what has developed into that system, until the witness, the jury, the judge and the advocate constitute the ideal court of to-day. Whatever else may be uncertain, the respective functions of these are not, and nothing is regarded as more essential in the administration of justice than that their distinct characters should be preserved. And yet the development of the system has been, as we have said, in the separation of the functions of these, combined primarily, to a greater or less degree, in the same individual or in the same body. Thus, originally the juryman was the witness as well as a judge of the facts: and long after jurymen were made judges of facts as given by others in evidence, the juryman still retained the function of witness, still was free to consider facts of his own knowledge in making up his verdict, as well as those received in evidence. To-day, a fact of his own knowledge is no fact at all to a juror in making up his verdict, except as it comes to him from himself as a witness on the witness stand. Again, so rigidly is a witness required to refrain from any assumption of the functions of the jury, that, whilst he may in a case for damages to land give his estimate of the value of the land before the damage at $5,000, and his estimate of $1,000 after the damage, he would be restrained from estimating the damage at $4,000, because it is for the jury to make the subtraction. This illustration, which is from an actual case, will serve to emphasize the present condition of minute differentiation of functions of the system, into which system, as it is at present, the scientific expert is to be fitted. Now he is, if not an entirely new introduction, at least but recently developed, as we have already intimated, by the intense and peculiar mental activity along lines hardly known to the ancient Greeks and Romans, any more than to our own savage legal ancestors, and coming in contact at multitudinous points with the individual and society. But the system of jurisprudence has lost, we might say, in plasticity by growth. With forms at first scarcely fixed and limited in number, it grew with the

requirements of expanding social conditions and material progress, it readily yielded to new demands upon it. But it has gradually become more rigid with fuller growth, until to-day it is strained by any effort or demand to accommodate it to the rapid progress of the race in very recent years beyond the conditions that shaped it.

As the scientific expert is classed, in the division made, as a witness, amenable to the same rules, without any discriminating marks, privileges or functions, a somewhat fuller consideration of this class may assist to a better comprehension of his status in the system.

Facts form the basis of judicial determinations. Their discovery and establishment form the fundamental part of judicial processes in all systems of jurisprudence. What is truth? is the first and all-important inquiry, or, as Bacon has put it, evidence is the lantern of justice. Here human testimony must always be the sole reliance. "All evidence rests upon our faith in it," with the latent fallibility of the senses, with the varying and undisciplined powers of observation, and with the perhaps still feebler power of statement and description, and withal with its liability to personal bias from interest or predjudice, or to sluggish indifference where these may be wanting. Many have been the expedients in all ages to enlarge or supplement human testimony, to test and purify it, to eliminate evident sources of error: and yet after all has been done by the best rules of evidence that large experience, combined with highest intellectual culture, could devise, there has always been, and always will be, that felt residue of doubt and uncertainty, which renders decision unsatisfactory or impossible, and which it should be the first concern of every system of jurisprudence to diminish. The highly cultured Greeks and Romans, to go back no further, skilled in dialectics, in all the arts that belong to judicial processes, resorted to the torture of witnesses to purify their testimony or to elicit fuller truth. Their great lawyers, to be sure, doubted its efficacy, and yet it remained, and in the nations adopting the Roman law grew into a still more complete, and almost diabolical system of procedure, even gaining an entrance into England in spite of

its want of harmony with the Common Law, or rather with the Anglo-Saxon character. The instruments of torture exhibited in the Tower of London are almost necessary to convince us on that point.

Where such agencies, which we might call natural, were not employed, the superhuman was called in; the Deity himself was called, or forced, into court. The old Germans thought their gods too just to suffer wrong to be done if in some way they could be made responsible for it; and the same feeling was represented in England before the Conquest, by the various forms of ordeal devised. The test of walking over nine red-hot ploughshares without harm, of thrusting the arm into boiling water, of enforced presence of the suspected murderer before the victim, that at his touch the wounds might flow afresh, and many similar devices are the expression of a felt helplessness in dealing with human testimony. After the Conquest, these forms were simply superseded by other modes of appeal to Deity, in the Wager of Battle, which remained law, though not practised, even down into this century. These are but a few of the devices to get at truth, or to shift the responsibility for failure; and, it must be remembered, that they are the desperate expedients, not of savage, or even of pagan nations alone. To-day, with the entire ruling out of the supernatural, we are in a condition to consider the question of rendering purely human testimony as reliable and complete as it can be made. Possibly, yet, the oath, as it is ordinarily administered, with its adjuration taken from the Roman law, may, in some cases, have the effect of an appeal to a superstitious regard for a conventional form of lie, supposed and intended to be, more offensive to Deity than a simple, solemn, deliberate "yea" or "nay." But in most cases I think it can be assumed that the fear of human punishment for perjury is uppermost. With this acknowledged reliance then on human testimony alone, the rules governing its employment have grown into a completer system, and it is under these rules alone that the scientific expert can come into court, and he must be made to harmonize with them, even if the value of his testimony, by no fault of his, is to

be seriously impaired. Let us see then where he gains an entrance under these rules. There is the first broad rule that testimony can relate only to facts; that inferences from facts are for the jury alone, as illustrated in the extreme application before given of the question of damages. There is the other equally broad and fundamental rule, applicable in all systems of jurisprudence, that the best evidence the case affords is to be given. But the ideal case of facts by the witnesses and inferences by the jury alone is difficult of complete realization. Facts and impressions from them often shade off so imperceptibly into each other, that they are not separable from each other in the minds of the witness, and there arises an apparent incompatibility in practice between these two rules; there occur cases in which too rigidly to exclude inferences by the witness would be to exclude the best evidence. A ready illustration is furnished by the question of identity. The impression, or belief on the part of a witness that an individual before him is the same that was seen by him at another time and place, may have the highest degree of certainty in his mind, whilst the facts upon which he bases it cannot be given in their entirety to the jury. He may exhaust his memory and his descriptive powers and yet there may remain a residue of facts, minute, inexpressible, inexplicable to the jury, more potent, perhaps, in forming his opinion than all that he could give. Legal practice, recognizing the existence of such incommunicable facts, admits the opinion of the only one in possession of these facts as evidence, admits them from the *necessity of the case*. So, again, a witness may have seen one man rush upon another and kill him; he may be able to give an opinion as to whether the latter had time to escape, because there are a variety of circumstances that could be pictured in his mind, but not detailed to the jury, which may constitute a large part of the aggregate upon which his opinion is based.

But again, in many cases, there are material facts upon which the triers of the cases, the jury, are not qualified, from their experience in the ordinary affairs of life to form an opinion, even when the facts have been admitted, or proved. Here again, from necessity, the opinion of some one

competent to deal with them must be taken or the rule of best evidence be violated. Thus we have opinions admitted as evidence, based not upon facts within the knowledge of the witness, but upon facts testified to by others. As an example, in a suit against a railroad company for damages, in the destruction of fruit trees by fire, a nurseryman, who has never seen the trees, may give an opinion as to the damages, based upon the testimony of others. Here then, we see the entrance of the expert witness, the skilled witness—known as well to the Roman law as our own—admitted in accordance with the rule of the best evidence, and the necessity of the case, as the text-book says, "on questions of science, skill, trade and others of like kind," which witnesses "are permitted to give their opinions in evidence as persons of skill." A better definition of an expert, than this from from Greenleaf, might be asked for; but, whilst any one with a few illustrations will form a general definition of the term expert witness for himself, the word seems to elude definition in terms entirely applicable, or at least wholly satisfactory in all cases, as they arise in practice. Judges and law-writers, in consequence, furnish almost numberless phrases definitive and descriptive of the term "expert," sometimes restricted within narrow limits, sometimes expanded so as to include a portion of the hazy, doubtful zone that separates the expert from the ordinary witness. The difficulty of precise legal definition of the term scientific expert is still greater. Besides special and peculiar knowledge and skill, it seems to imply broader, more comprehensive knowledge, involving general laws and principles equally with specific facts, a result not of skill and observation alone, but of a wide range of reading and study as well, accompanied by that intellectual culture and discipline that permits the possessor to draw upon the whole range of human knowledge in settling questions that may arise. One of the simplest and most noted cases will furnish facts illustrative of the distinctive characteristics of the scientific expert, and also serve a further purpose. A man was accused of poisoning his wife by a draught of medicine containing arsenic. The chain of circumstances fixing

his guilt seemed complete, yet there was wanting positive proof that the draught administered contained arsenic. The cup in which it had been was cracked by heating it on the stove, but the spilled liquid had been immediately carefully wiped off by the accused. All ordinary witnesses were at their limit. Ordinary human testimony could go no further. The question was put to the four scientific experts: Whether arsenic could still be detected upon the stove, after three months of constant use. Three of the experts said No; the fourth gave his opinion that it could. The accused, persuaded by his counsel, demanded an examination of the stove, trusting to the care with which he had removed the liquid. The experts and the judge went to the place. Half as much rust as would lie on the point of a knife was scraped from the designated spot, and in a short time evidence of the presence of arsenic, incontestable, satisfactory to all the experts, to the jury and to the judge was obtained. The single missing link in the chain of circumstances was thus supplied with inerrant certainty. Here, then, was evidence only obtainable through a scientific expert, and what was perhaps equally as important, only to be fully and satisfactorily confirmed by the opinions of others of the same character. Now this is certainly the very highest type of human testimony; at one time contributing facts of peculiar and unmistakable character, at others interpreting by infallible methods facts testified to by others. The scientific expert is in court then because of high peculiar value in his evidence. He has hardly forced himself in. He is scarcely in, in the first instance, by simple invitation but rather by the irresistible persuasiveness of a *subpœna*, which he is not at liberty to disregard any more than the ordinary witness. That he is in court to stay it is hardly necessary to assert, certainly not to argue. But with the rapid advance only of the past twenty-five years, in minute, detailed, exhaustive knowledge, in special knowledge, with the manifest tendency to precision in everything, even the sports of children, and at the same time with the broadening of the field of applications in all directions, all dumping in, as it were, new matter upon the courts for consideration, matter which

they are in many respects unprepared, if not utterly incompetent, to deal with, it does not seem that the question of the future will be whether the scientific expert should be in court, but the grave question should be, as the pressing question is, whether his contribution may not be made more effective, less clouded and weakened than it now seems to be in the minds of many jurists, as the inevitable effect of a rigid system of jurisprudence, fashioned long before he was a recognized agent in forensic procedure.

In considering some of the sources of dissatisfaction with the scientific experts, perhaps one of the first to suggest itself, and one of the most prolific, is the vagueness of the legal definition of the term "scientific expert" before alluded to, but which on more careful consideration might rather be termed vagueness and variableness of the standard. Definitions of things are of ideals, and consequently definition is followed closely by the statement that the thing defined is non-existent. The ideal circle is defined, so the ideal solid, the ideal liquid; these definitions are only approached, never realized. Degrees of approach constitute the differences. A few minutes ago we broadly sketched a bundle of qualities that should be found in the scientific expert. But practically the courts are limited to the best experts extant in any field, though they may at times fall far short of the ideal. But it is to be feared that in many cases the experts fall below a reasonable and possible standard, and far below the standard that would be fixed by scientific men themselves, as well as below the exigencies of the case. This may easily be accounted for. A party presents a witness as an expert. The judge must pass upon his competency upon such examination as he can make. That decision, though not necessarily, nor even by unvarying practice, a matter of discretion, will not often be reviewed by a superior court. Often then the best solution, certainly the easiest, seems to be to admit, even where there may be grave doubt as to qualification, and to throw the burden upon the jury, already overburdened with questions, which the theory of trial by jury assigns them, questions which they are not qualified to deal with, although they may be fully up to the

average in general intelligence. At a time when experts were not much beyond men in the ordinary avocations of life it may have been reasonable to require the jury to pass upon the "weight and credit to be given to evidence viewed in connection with all the circumstances," but under the changed circumstances of to-day, with experts of a character, and upon questions not dreamed of even a century ago, it seems to be straining a theory too far to put upon an average jury the decision of so grave a question, as to the character of the expert, which the court may not be able to settle satisfactorily. But for the theory it would not be thought of, if a system of jurisprudence were now being devised. Now among the results incidental to a liberal interpretation of the term by the courts are many that are regarded as the gravest evils of expert testimony. With doors wide open to incompetent persons, very slight pecuniary advantage, and still more frequently the incidental benefit attributed to notoriety and advertisement would cause them to seek entrance. As a result differences of opinion may be anticipated where knowledge is wanting as a basis. Then, too, the number of such experts in any case will be greater. The cross-examination, absolutely necessary to test such evidence, must be exhaustive and tedious. Trials are prolonged. The expense of the administration of justice is increased without furthering its ends, and withal often with incidental discredit not only of the testimony of experts, but in a measure of the whole judicial procedure which is responsible for them; and the jury are often left in such a state of mental confusion that the evidence can only be weighed by counting the experts. Now the rule should tend toward a greater strictness in regard to the qualifications of experts, since the progress of science tends towards a greater degree of specialization in study, and consequently to more minute and extended evidence on the whole, with greater restrictions on the range of best evidence of any particular expert. If science stood still, or if forensic science was confined at all times to the same old ground, everything would be settled, but as it is, the new points at issue continually arising make new demands upon experts, which

there may be few at first qualified to meet. We might fill in the evening with interesting cases illustrative of this point. The introduction of advanced scientific expert testimony is then hardly a matter of option. It is forced upon the courts by the fact that science is just as ready in the hands of the unscrupulous and dishonest to perpetrate the most flagrant wrongs as to aid in their detection, and that there is no advance in science that is not as accessible to the enemies of society as well as to society itself.

But another, even more prolific source of complaint than laxity of rule in the admission of experts, lies in the anomalous position of the expert in many respects, and under the best circumstances. He is legally a witness, an ordinary witness, but practically with extraordinary functions, and loaded with extraordinary responsibilities, and one might add, frequently loaded with extraordinary, and even absurd, expectations. As a witness he is subpœnaed by the same form, obliged to respond under the same penalties, to take the same oath; is subject to the same rules and restrictions, and the same treatment in court. He has no higher claim upon the State, or upon the parties for his time or his private professional knowledge, which constitutes his livelihood. He receives, in most cases, to be sure, from the party calling him, a fee agreed upon between them, and certainly out of proportion to those of other witnesses, even if it is not professional in magnitude. He assists the side on which he is called in working up its case. He suggests cross-examination of witnesses. He thus exhibits the character of a very willing witness, of a well-paid witness, combined with a great deal of the advocate. Now he cannot be held responsible for this position, but the system of jurisprudence, which not simply permits it, which has not simply taken him, but has forced him in, and which, apparently cognizant of all, seems only able to originate complaints, rather than to provide a different character for him; for there seems, indeed, in many of the adverse criticisms of experts, to be only a confession of weakness, rather than a disposition earnestly to consider the whole question with a view to the radical remedy of the evils. The human nature of the judge is

recognized and provided against. Every safeguard is thrown around him to protect him from bias, or possible suspicion of bias, which would be almost as bad. The jury is selected so as to be free from bias, and is protected as well. Other witnesses are not expected to take the part the scientific expert is almost compelled to take. In fact, if deliberately planned, there could hardly be a net-work of conditions, devised, calculated to produce so many of the evils of scientific expert testimony, complained of, or to cloud this testimony of highest intrinsic value, having the highest degree of certainty, and in a field altogether its own. Thus, in the extract from *Taylor on Evidence*, stress is laid on "the facility and extent to which their views can be made to correspond with the wishes and interests of the parties who call them," "though conscientious they are biased," "they are embarked in a course," "they are selected on account of their ability to express a favorable opinion, the result alone of employment," "they are adroit advocates of the theory of the party calling them," "men of the highest character are apt to be prejudiced," and so forth. Now the worst views thus expressed may be admitted in many cases, and yet there is a pertinent question of fact suggests itself, viz: In how many cases does favorable opinion, or bias, if you please, precede the call of an expert, rather than depend upon the call? And the still more pertinent question: How many experts are not in the particular case because their opinions are not wanted by the party who consulted them. There seems to be in mind in the consideration of experts too much of a similitude to the attorney. An attorney is employed. As a rule, I suppose, he accepts employment without any very close examination of the case to see whether it is the right side that seeks his services. I do not know that legal ethics requires him look too closely into the matter. In any event, there is sure to be one attorney on the wrong side. This is incident to the profession. But I think it would be found that there are few cases in which a scientific expert is actively engaged on a side contrary to his convictions; and convictions resulting from a careful examination of the cases. He would feel that his character as a

scientific man was too deeply involved, whilst the professional character of the lawyer would not be, but the worse the case sometimes the greater the professional credit. In many of the opinions quoted instead of "bias of experts," "convictions of experts" might be substituted, earnest convictions and convictions, or bias if you please, not produced by or dependent upon the call or employment, but upon expression of which the call or employment is based. The man of earnest conviction becomes the earnest, perhaps the adroit advocate of his theory, the enthusiastic aid of the attorney in preparing and even in conducting his case in court; and an attorney does well to secure his services, as well as his testimony, by a suitable pecuniary recognition of his worth to him, and there is no rule of ethics that I can find, that should cause the expert to refuse the reward of his labor, that would not apply equally to the attorney, so long as his testimony on the witness stand is without conscious untruth. On the other hand, neither is there anything in legal ethics to require a lawyer to select a lukewarm, half-convinced representative of his theory of the case, and we may assume that, with the whole range of scientific experts to select from, he never does. Illustrative cases of these statements are within the experience of many. That the expert should occupy this position of witness and quasi-advocate at the same time may very naturally be criticised. But it is permitted; more than that, it is expected, if he is well paid, that he shall assist in working up the case. Even more than this, he is a necessity in this *rôle*, as well as in that of witness, and the legal mind sees no impropriety in it whatever. A writer on this subject, who is keenly alive to the abuses of expert scientific testimony, in urging cross-examination as a means of exhibiting any inherent weakness of expert testimony, and recognizing that this requires an approximate degree of expert ability on the part of the cross-examiner, as cannot reasonably be presumed to belong to the legal profession, suggests, as one of the modes of informing himself, "the advice and explanations of his own skilled witnesses of the false or unwarranted positions and deductions which his adversary is likely to

assume." If there were no one to do this work, and scientific expert testimony had to be accepted without cross-examination, or even feeble cross-examination, such as the ordinary attorney unaided might be able to give, the question of its exclusion in many cases might be a very proper one; and yet a seeming inconsistency, or rather incongruity, is imparted to the character of a witness who passes from the table of counsel to the witness stand to testify, not to facts, but to opinions; and as a consequence, we might expect his testimony to be misunderstood and harshly judged.

But in regard to the charge of bias, so freely made, it may be admitted that the scientific expert may at times be biased, but that is only admitting that he is made of the same clay as other men. The bias, if not produced by the call, would certainly not be more of a reflection on his character than upon the system of jurisprudence which renders a call based upon bias not only possible, but almost necessary, and which provides no other method for the introduction of scientific testimony. But bias may be in nowise incidental to the call. It may be a purely scientific bias, due to some peculiar view or theory. No kind of training will fortify a man against bias at all points. In his laboratory, in conducting his investigations, the scientific expert may keep himself free from bias. The judge upon the bench is free from bias by habit, rather than by conscious effort. But even the judge, placed in some novel position of great responsibility, which this judicial habit does not fit exactly, might lapse into a bias. It is but a few years since that the American people trusted the decision of a grave question to a tribunal made up of judges of the Supreme Court, of Senators and Representatives of high character, picked men; and yet the points before that tribunal were decided eight to seven, always the same eight, always the same seven, always along the same line of division. I think there is a feeling to-day, not of reproach for, or distrust of the tribunal, but that it was hardly fair to have imposed that work on that tribunal under all the circumstances, and that it will never be repeated.

Another source of misunderstanding between the legal fraternity and experts lies in the decided difference in mental attitude with which they come to the trial of cases, a difference that often tends to produce feelings other than those of mutual respect. This can be well emphasized by quoting again from the lecture on "Medical Expertism" by a learned judge. He admits, "that there is abroad in legal circles a tacit sentiment, that for the evils of the expert system their profession is nowise responsible, and that with the medical profession rests the primary liability for all the admitted ills of this department of jurisprudence," which he attributes to differences between the mind medical and the mind legal, regarding the professions as "types respectively of the inductive and deductive in science." But, even if such a difference be admitted, there is a wider difference in the motives. We may assume that the scientific man comes into court with the mental habits of the investigator and expositor of science. There is sincerity of purpose, a mental candor, a tendency to look for truth wherever it may be found, and to conceal nothing. The true scientific man would be very awkward in advocating a proposition he did not believe, even if he could be induced to do so. He would not prove at least an adroit advocate. He notes soon that the attorney is only intent on winning his case; that Strepsiades himself could not be less indifferent to the question of right in the case. And whilst he may regard the distrust of testimony on the part of the lawyer, as fully justified, and feel that his extreme scrupulousness in admitting as uniform truth any human testimony until it has been thoroughly sifted, may be the result of habit, or be due to his larger experience with it, he becomes slowly impressed with the other fact, that he has no desire for scientific truth which does not affect his side favorably, and that he has great aversion for, and desire to repress, what might affect it unfavorably. He may become impatient of cross-examination that does not seem to be altogether in the interest of truth, and irritated by rules that control him, and that, perhaps in his judgment, distort and mutilate his testimony, and his opinion of lawyers may be affected unfavorably. That I have not done injustice to

the legal fraternity in attributing this difference of motive in dealing with scientific testimony, let me quote again from the lecture last noticed. It reads: "The lawyer discriminates between the practitioner and the expert, embodied though they be in one and the same person; at the bedside he reposes a practically unlimited confidence in the man as a physician and in his science; as an expert he regards him as a tool whose cutting edge he will employ, or dull, as exigency may require." The ground of dissatisfaction on the part of the expert seems to be displayed in that last sentence. In the trial of cases it is the art of law rather than the science of law which the scientific man comes in contact with. The practitioner and the court are concerned mainly with and solicitous about the distinctions and technicalities, the well-worn rules of practice, often *placita juris* rather than *regulæ juris*, the tools and machinery of the law, and the exercise of mental dexterity in their use and application. The rules themselves may have been formulated long before the scientific expert was known in the world of jurisprudence, and not in contemplation of him, and as far as he is concerned may not therefore be the perfection of human wisdom.

The criticism due to differences of opinion frequently exhibited by scientific experts can hardly be regarded as a serious matter by a profession characterized by differences of opinions on all conceivable points; the only settled opinions known to it being those of the court of last resort, which even claims the privilege occasionally of reversing itself. Differences of opinion among scientific experts are often doubtless due to differences in scientific character, resulting from the loose rule of admission. But there may still be honest differences between experts of highest character. I think such, however, it will be found, are rarely in regard to well-established facts, but oftener in regard to probable inferences from facts, whilst entire agreement would be marvellous in matters of theory and speculation. Courts and attorneys do not discriminate sufficiently between well-established scientific facts and scientific theories. Some of the most recent and far-reaching decisions of our highest tribunals have a basis of theory rather

than of fact. In the cases cited in the beginning three experts gave an opinion that arsenic could not be found under the circumstances, a fourth thought that it could, further opportunity alone demonstrated the correctness of the latter, and brought all the experts into accord.

So, too, the tendency of the scientific expert to usurp the functions of the jury, or even of the court, magnified so greatly by legal minds, may possibly exist as a result of his ill-defined position, or perhaps from imitation of the good judge, who is credited with tending to enlarge his jurisdiction. This should easily be corrected, with the intelligent expert, by the rules and ample power of the court. There is no time, and it is not necessary to go further into the consideration of the evils and abuses of expert testimony. Sufficient has been given to indicate that there are two sides to the question; that the expert is not altogether to blame, but that the system of jurisprudence, with feebler powers of adaptation and assimilation has had changed conditions and new material thrust upon it more rapidly perhaps than at any other period of its development. The disposition is perhaps first to complain of innovation. But that must, and will soon, give way in the case of the scientific expert, to a disposition to consider more carefully how the highest utilization of this new source of evidence can best be secured, unclouded by unnecessary conditions. It will not be an easy task. It certainly should not be done hastily, or in a revolutionary spirit, nor be trusted to inexpert lawyers or legislators; but once seriously undertaken, in the proper spirit, it will be on the way to accomplishment. Practices of which courts have grown ashamed have been radically changed in not very remote years. Some of the directions of reforms have been indicated. Whether these should come by the slow process of judicial legislation, or by statutory enactment, is matter of indifference. As the under-workman of the legislature, as the judge has not been inaptly termed, is responsible for much, much might be left with him to reform, but the process may be too slow to be satisfactory. A more rigid enforcement of a higher standard for scientific experts is certainly largely in the hands of the judge, and

as we have said would abate many of the most serious evils complained of. In this connection, the encouragement of regular professional experts might be of advantage. There is at times a disposition to disparage the scientific man who figures frequently, or professionally, as an expert, outside perhaps of medical cases. But there can be no question that such experts facilitate the trials of cases, remove many of the asperities, and economize much time. They acquire a familiarity with the rules of practice, and acquire a self-command, under cross-examination, of the most unreasonable and even exasperating character, which at times will allow it unopposed to expend its energy in useless directions in the shortest time. In a conversational discussion of this subject, the experience of a prominent attorney with a prominent scientific gentleman, who figures frequently in court as an expert, and of whose integrity, from personal acquaintance, I have no shadow of doubt, transpired. The attorney had encountered him frequently in trials. He had in cross-examination built a pen around him, as he expressed it, higher and higher, until he saw no possibility of his escape, when, in his words, he cleared the whole at a bound, and he came to regard him as impossible to trap. With a less experienced expert such examination might have been much more prolonged, than with one perfectly self-possessed, and perfectly sure of his position, and truth even might have suffered; but he could afford to allow the attorney to have his own way, seeing clearly the end from the beginning of the cross-examination. But besides the shortening of cross-examination, professional experts would greatly facilitate the procedure of the court by knowledge acquired of the character of the parties for and to whom evidence is to be given, as well as a power of presentation and exposition to suit the case. Such experts would not have to explain their meaning to a jury, and then, perhaps, have to explain the explanation.

We have seen that many of the most objectionable features of the expert witness originate in the mode of his entrance into court, and it is an allowable question, whether any modification could be made in the calling of the wit-

ness. Among the reports one judge expresses the opinion that, "expert witnesses ought to be selected by the court, and should be impartial as well as learned and skilful. A contrary practice, however is now probably too well established to allow the more salutary rule to be enforced." Another judge suggests, that the law should be so changed "that this class of witnesses should be selected by the court, and that this should be done wholly independent of any nomination, recommendation or interference of the parties, as much so to all intents as are the jurors." This would not make experts *amici curiæ* any more than before, for all witnesses should be regarded in that light, but it would be a provision, rather, to preserve that character to them, coupled as it is with a recommendation as to compensation, so intimately connected with it. It is not the fact of extra compensation, or that the compensation is paid by the party benefited by his testimony, that creates the unfavorable impression. The other witnesses are friends of the court, by whatever party they may be called, they stand upon the same footing as to pay; but here is a witness who is paid according to a private agreement, by one of the parties; the amount is their own private arrangement on which the court is not consulted, over which the court has no control, a circumstance that imparts to him, in high degree, the character of a friend of one of the parties; and these facts as to compensation are often elicited at a time, and in a way, calculated to impair otherwise valuable testimony, in the minds of the jury.

Again whilst a *subpœna* may be made to cover an expert, simply because "he is accomplished in a particular science, art, or profession," as well as a person who has from his own observation "knowledge of a fact pertinent to the issue to be tried;" and although it may command his presence, as in our State of Pennsylvania at least, without any claim for extra compensation, it cannot "compel him to examine the case, and to use his skill and knowledge to enable him to give an opinion." His testimony may accordingly only consist of impromptu answers, which may fall far short of the standard of best evidence the case is susceptible of. A

lawyer, or a judge may be considered an expert on matters of law, and yet neither would give an off-hand opinion on all questions that might arise, nor might we desire it upon questions of great intricacy, or involving grave interests. But either could in a short time, from their professional familiarity with, and ability to consult, books, give an opinion that would be perfectly trustworthy. The same is true to almost an equal extent with the scientific expert. He can give impressions, not guesses, upon points which would rise to full grade of opinions and beliefs with proper time and facilities for investigation. His knowledge from books is as much a part of the knowledge from which he is permitted to testify, as that from his own experience. It has sometimes been suggested that under the Constitution the accused has the right to compulsory attendance of expert witnesses, and yet whilst with an ordinary expert witness it might be a right with some benefit, with a scientific expert indisposed to examine the case it might be an empty, fruitless right. Such a witness, though covered by the language, could hardly have been contemplated by the Bill of Rights. Now then as the State cannot command this evidence, and it is not obtainable, in most cases at least, without compensation, the recognition of the particular character of such evidence, and the regulation of the compensation might relieve it of some of its most objectionable features. The question is not so much whether the expert should be compelled to testify, as to whether he should in some degree at least be compensated for his professional time which is his own private property, and not be afflicted because of his professional knowledge. Private property is taken for public uses continually, but in all other cases upon just compensation. There cannot be the same plea of necessity for his evidence that would make it a public duty to testify as in case of other witnesses. The latter are in possession of specific facts which happened to fall within their own knowledge, and of which no others may be cognizant. At this point of compensation the law is variable and practice unsettled. In Pennsylvania, the scientific expert is an ordinary witness in all respects. He can be

taken from one end of the State to the other on ordinary witness fees and mileage. In English practice extra compensation to a scientific expert may be taxed as part of the costs. The compensation is, however, based on the superior value of his time, rather than on the value of his services. It is not professional compensation. So in the Imperial Courts of Germany, the experts, whether of the class of permanent ones, appointed by the State, or those appointed in particular cases by the judge, can demand a certain payment, which, however, in this case also is regarded rather as a restitution in money for his loss of time, than as payment for his work. In the opinion previously quoted from Judge Redford, in regard to selection of jurors, he makes the additional suggestion to the end that experts may be appointed by the court, "that the compensation of scientific experts should be fixed by statutes or by the court, and paid out of the public treasury, and either charged to the expense of the trial, as part of the costs of the same, or not, as the Legislature should deem the wisest policy." In some of the United States, very few it is true, a move has been made in that direction. In Massachussets special compensation to experts for the defence is allowed to be paid out of the public treasury, thus insuring the effective attendance of a witness of this kind, resting not simply on compulsory process. With the regulation of the appointment, selection or employment of experts, whichever word may be used, and the question of compensation removed as far as possible from the decision of interested parties, many of the ugly features of scientific testimony will disappear, and, perhaps, much that is untrustworthy or dishonest.

In the discussion of the question more radical reforms are sometimes suggested, such as to have permanent experts appointed by the State, to be paid by the State as officers. So it has been suggested to give scientific experts determining functions independent of, or auxiliary to, the court and jury, to introduce a sort of fifth factor in judicial procedure. Any such innovations can only come with full consideration, and as time with its growing demands indicates, by process possibly of further differentiation, possibly by assimilation

of reforms suggested by other systems of jurisprudence. But, whilst it might be a pertinent question in this connection, whether similar evils are complained of and to the same extent in continental practice in Europe, too much is not to be expected from this source. Excellencies of other systems might not bear grafting on the English stock. Systems of jurisprudence are growths, not aggregations, and Bacon rated as one of the excellencies of the Common Law that it was made for the English and not for another people. Still the scientific expert is equally recent in all systems, and treatment of him in one may have valuable suggestions for others.

As I have alluded to German practice on one point, a few others may be of interest. For certain matters and lines of business permanent experts are appointed by the State, but they are are not regarded as officers, but as employés for the time being. They have no official title, nor regular salary. The payment they receive is not enough to support them, but barely compensates them for their loss of time. For most cases the expert is appointed by the particular judge in the case, often on the demand of one or the other or both parties, but the choice of the expert lies within the discretion of the judge. He may appoint any man whom both parties suggested, or may also appoint a third man not suggested by either, but if both parties unite on one man he must listen to his testimony. If a question is involved for which regular legal experts are provided, these need only be, or can be appointed. The qualifications for such a regular expert are that he should follow that particular profession or line of business habitually, and for the purpose of earning his living. The number of experts in a case is not limited by law; it rests with the discretion of the judge. The status of the expert in court is almost analogous to other witnesses, but it is not a civic duty, as with witnesses, to give evidence in court except where a profession is followed publicly and for a livelihood. The text of his oath before giving testimony is different from that of an ordinary witness; and he need not be sworn at all if both parties unite in dispensing with such qualification. The systems

of jurisprudence are so different comparisons are difficult. But there are some indications of a fuller recognition of an expert class of witnesses, but at the same time no suggestion of an expert class of Government officers.

I have thus endeavored, within the time limit of a very patient audience, to discuss the subject announced rather comprehensively and suggestively than minutely or even systematically, and I will have accomplished my purpose completely, if I have succeeded in presenting a few of its most salient features, in such a way, that the general public, outside of the professions involved, may have a juster view of the scientific expert and the position he occupies in forensic procedure, and that it may be impressed, to some degree with the fact, that the testimony of scientific experts is at present an important factor in the trial of cases, ready in the near future to add to this importance in directions we cannot even predict; that the courts are powerless to exclude or restrict it if they would; that its present status is unsatisfactory at many points, and demands the most serious consideration of all interested in the proceedings of our courts that its value be not impaired by unnecessary taint, and that the best evidence that the most advanced science has to offer is utilized in the trial of cases.

ROPE-POWER TRANSMISSION.

By James M. Dodge.

[*A lecture delivered before the Franklin Institute, December 2, 1892.*]

The lecturer was introduced by the Secretary and spoke as follows:

Members of the Institute, Ladies and Gentlemen:

Rope-power transmission is comparatively a development of recent times. Although ropes were used in isolated cases for this purpose many years ago, it may be said, so far as this country is concerned, that the last ten years have seen the adoption of rope-power transmissions become more general and the system take a recognized place in the field of mechanical engineering.

There are two general systems in vogue, which may be designated as the "English" and the "American." The former employs one or more single ropes, whereas the latter uses one continuous rope and employs a tension carriage, operating on one of the turns of the rope, to insure a uniform amount of work being performed by each wrap around the wheels.

Wheels, or sheaves, used in connection with the rope for the purpose of transmitting power, are made with V-shaped grooves in the rims, the most commonly accepted angle being 45°. These grooves are made sufficiently deep to prevent the rope bottoming, or resting upon the bottom of the groove, the object of this being to increase the resistance to slipping and enable a moderate weight on the tension carriage to give sufficient driving force.

Sheaves used in conjunction with manila rope are made in two ways, the older method being to cast the sheaves with sufficient width of face for the number of grooves desired and to roughly core the grooves, so as to lessen the amount of iron to be removed by the turning tool in finish-

ing them. It is necessary to cast the wheels sufficiently heavy to resist the pressure of the turning tool, in order to have the finished wheels as round as possible. It is almost impossible, however, to avoid a small amount of spring between the arms, so that upon careful measurement the wheel is found to be polygonal. This is notably the case when the cut is heavy, it being necessary, in order to obtain a good result, to take a roughing cut, which releases the skin tension of the casting and permits it to take a modified shape, due to the internal strains ever present in cast-iron wheels designed to have the outer surface removed from them by turning. Then a second cut is taken, and finally a finishing cut is made with a tool ground to the exact shape of one of the finished grooves, this last cut, which is made more to true up the inequalities of the previous work, removing but very little metal. In the foundry work connected with the manufacture of these wheels, it is seldom that a wheel having two or more grooves in it is so perfect that upon turning imperfections are not discovered. These, of course, if too numerous, render the condemnation of the casting necessary. If, however, the sand holes, or blow holes, in the turned surface of the sheave are not too large, they are filled with babbitt metal, and the sheaves are put in use. The amount of metal turned from castings for rope sheaves is astonishingly large; for instance, in the case of a five-groove sheave of forty-eight inches diameter, for one and one-eighth inch rope, the rough weight before turning was 698 pounds, and after finishing the weight was 567 pounds, showing that 131 pounds had been turned off the original casting. This proportion would, of course, vary somewhat, dependent upon the care taken in the foundry, but at the same time it is always greater than would be supposed.

The second and newer method of manufacturing sheaves is that practised by the "Link-belt" companies and differs from the already described method in two very important features. In the first place, the sheaves are not turned after being cast, great care being taken in the proportioning of the hubs, arms and rims, so that the castings can be made of

extreme lightness, but being devoid of internal strain are very strong. The grooves are cast on green sand cores, a three-part flask being used. By this we mean the flask has a cope and a drag, as is common in all foundry work, but between them is placed what is known as the "third part" or "cheek piece," which holds the sand destined to form the grooves in the finished wheel. It has been found in practice that it is possible to cast sheaves in this manner that are fully as accurate as turned ones, and with an average saving in weight of 17·2 per cent. This saving in weight, of course, effecting a corresponding economy in the power required to operate a rope drive furnished with them.

The second radical difference between the "Link-belt" sheaves and the solid turned sheaves is, that the manufacture of multiple groove sheaves, or those having more than one groove, is effected by bolting together what are known as arm sections (which are really complete sheaves of one groove) and rim sections (which are simply grooved rims cast without arms or hubs). This plan makes it possible to vary the weight and strength of multiple groove sheaves by using a greater or less number of arm sections, dependent upon the size of the rope to be used and the varying conditions of their employment. After the sheaves are "built-up," as it is termed, they are bored out, and to show the trifling difference in weight between the rough and finished sheaves, I would state that a forty-eight inch five-groove sheave for one and one-eighth inch rope weighs in the rough 433 pounds, and when finished 423 pounds, or 144 pounds less than the finished solid-turned sheave referred to previously.

So great is the care taken in the casting of "built-up" sheaves, that the only finishing required in the grooves is that of smoothing the casting by holding a block of emery in the groove while revolving at a speed of about 120 revolutions per minute, the finishing of each groove in this way not occupying more than three or four minutes.

An incidental advantage of the multiple groove "built-up" sheave is, that after a rope drive is erected and the

necessity arises for the transmission of more power than that for which it was originally designed, additional ring sections may be added to the sheaves, and by splicing in an additional piece of rope, the desired increased transmitting capacity may be secured.

It is obvious that in the use of a single rope making a number of wraps around two wheels, it is essential that the diameters of the grooves at the pitch line, which is the arc of contact of the ropes, must be uniform in all of the grooves in any one sheave; otherwise, there would be a tendency on the part of some of the wraps of the rope to travel faster than the others, which tendency must be counteracted by the slipping of the rope in some of the grooves, this, of course, resulting in a loss of power and also in the rapid wear of the rope. So important is this feature, that great care has to be taken in splicing the rope so that the diameter at the splice will be no larger than in the body of the rope. An increased diameter at the splice would, of course, make the splice travel around a larger circle on the sheave by its not being able to take as low a position in the V-shaped grooves.

It is impossible to splice a rope without impairing its strength at the splice, provided its diameter is not increased. What is ordinarily known as the "short splice," or the "long splice," as used by sailors, will not answer at all. It is essential that a splice (for instance, in a rope one inch in diameter) should be from ten to twelve feet long, and made with great care, so that after the splice is complete the tension to which the rope is subjected is evenly divided among the strands of the rope.

Durability of manila rope transmissions is dependent upon various conditions, the most important one probably being the quality of the rope. In order to make good rope it is necessary that the fibres employed in its manufacture should be long and of nearly uniform size. The fact that the fibres of manila have a rough interior and are of great strength in proportion to their weight, is an important factor in the strength of the rope when subjected to a tensile strain, but at the same time this very roughness becomes

an element of destruction when the ropes are passing around sheaves which cause the fibres to slide upon each other so that the internal wear of a rope becomes a most serious agent in destroying it. A worn-out rope untwisted so as to expose the strands, will show a fine powder which has been chafed off the fibres. Of course, after this has been detached from the fibres, it leaves them weaker than in their original condition. It is also noticeable that the fibres of manila, being composed of elongated cells, are not perfectly adapted to continued bending.

In order to counteract the destructive tendencies enumerated, it is essential that the rope should be lubricated. This is accomplished in two ways, the first being by the introduction of a lubricant in the manufacture of rope; notably, as in the case of what is known as the "Stevedore," into which tallow and graphite are introduced at the time the rope is made, the effect being to increase the flexibility of the rope, increase its life and to render it to a degree water-proof, and also in the ropes of some other makes, which are laid with tallow. The second method is to coat the outside of the rope with a mixture of lampblack or graphite and grease, relying upon the working of the strands of the rope with relation to each other to work the compound through it. This latter method is practised on the Continent, and is also being made use of in this country to a considerable extent.

Some of the larger constructors of rope transmissions in England claim that manila rope should never be used under any circumstances; that cotton is the only fibre that will give satisfactory results. I have seen samples of a rope one and three-eighth inches in diameter, which had been in constant use ten hours a day for nearly sixteen years. This was a cotton rope, known as the "Lambeth," the peculiarity of its construction being that it was primarily made of cotton, but each of the four strands of the rope was covered with a number of tightly twisted yarns, forming a protecting envelope, which prevented cutting or wearing of any of the strands proper of the rope. Of course, cotton ropes are much more expensive than manila ones, and a rope such as

the "Lambeth" must necessarily be the most expensive of those made of cotton.

It is unquestionably true, that in time cotton ropes will be more extensively used in this country, crowding out the use of manila; but it is a fact that the introduction of any radical departures in the field of mechanical engineering are only possible by offering not only a more satisfactory article than has formerly been used, but also a cheaper one. This fact has aided in the introduction of the manila rope drive, as in many cases it is not only the best means of transmitting power, but also the cheapest. Ultimately, and as users of rope drives become more familiar with their intrinsic advantages, they will be more ready to increase the original outlay and put in the best rope that can be made.

If manila rope transmissions are designed with good judgment and are properly erected, there is no possible doubt of their giving satisfactory results. The prevailing notion is, however, that as rope is flexible in all directions, rope drives can be constructed in a haphazard manner, without special care being exercised in getting the sheaves in exact alignment, and considerable criticism has been engendered by lack of attention to the important details. When borne in mind that a rope used for the transmission of power runs at a speed as high as 5,000 feet per minute in many cases, and as a rule the rope is run in close proximity to the ceiling, which is the hottest part of a room, it is not surprising that the rope rapidly becomes dry and correspondingly brittle; hence, the importance of lubricating it in some way, to counteract the drying tendency. It is not uncommon to find rope transmissions erected so that the sway of the rope will occasionally bring it in contact with a beam, which, of course, results in extremely rapid wear of the outside of the rope. The fact that conditions of this kind exist is sometimes hard to discover, as when the rope is at rest it may apparently have abundant clearance throughout the path of its travel. One case brought to my attention, in which the rope was being rapidly worn out, resulted in the discovery of the fact that in its passage through the

wall of a building, the rope would sway and come in contact with the edge of a corrugated iron covering of the building. On calling this condition of affairs to the attention of the parties operating the drive they seemed quite surprised that such a trifling thing as an occasional touching of the rope on the corrugated iron should in any way impair the life and usefulness of the rope.

Manila rope is usually run under a working strain equal to three per cent. of its ultimate breaking strain and at velocities varying from 3,000 to 5,000 feet per minute.

To determine the power which any rope will transmit at a given speed, it is necessary to ascertain the nature and amount of the strains to which it is subjected while running, and then to find the exact part of the total working strain which is expended in performing useful work.

Generally speaking, ropes in the "American" system are subjected to three principal strains, viz: the strain due to the power transmitted; that due to centrifugal force; and that due to the tension carriage weight. Besides these three there are the minor strains, due to the weight of the rope, the internal resistance of the rope to bending and the strains required to make the rope enter and leave the wedge-shaped grooves. With good ropes, running in well-made grooves, the minor strains do not probably absorb more than five per cent. of the working strain of the rope.

As an illustration of the method of determining the horse-power of a rope in the American system, let us assume the case of a one-inch rope travelling at a speed of 4,500 feet per minute. The breaking strain of this rope, as given by the Plymouth Cordage Company, is 9,000 pounds, and according to the limitation imposed by good practice, the total working strain should not exceed three per cent. of this, or 270 pounds. Deducting five per cent. for the minor strains, we have 257 pounds, which represents the sum of the three principal forces.

In order to obtain the effective strain, or driving force, it is first necessary to find the strain due to centrifugal force. This force varies directly as the square of the speed, and may be found by multiplying the square of the speed

in feet per second by the weight of one foot of rope, and dividing the product by thirty-two.

Now, the weight of one-inch manila rope per foot is ·33 pound, and the centrifugal force, therefore, equals

$$\frac{75^2 \times \cdot 33}{32} \text{ or about 56 pounds.}$$

Subtracting this from 257 pounds, we have 201 pounds as the sum of the strain due to the power transmitted and the strain due to the tension carriage weight.

Now a series of carefully conducted tests have established the fact that a weight of (say) fifty pounds on one end of a rope wrapped half way round a sheave having a 45° V-groove, will sustain, without slippage, about three and one-half times its weight at the other end of the rope. Assuming, for the sake of safety, that this ratio is as 1 : 3, it is evident, that to sustain a strain of 201 pounds on the tight side without slippage, it is necessary to maintain a tension of one-third this amount, or sixty-seven pounds, on the slack side. The effective strain, or driving force, will, therefore, be equal to the difference of these strains, or 134 pounds, which at 4,500 feet per minute will transmit

$$\frac{4{,}500 \times 134}{33{,}000} \text{ or } 18{\cdot}4 \text{ horse-power.}$$

In the same manner we find, that at a speed of 1,800 feet per minute, the centrifugal force is only nine pounds, and the effective strain is 166 pounds, transmitting nine horse-power; while at a speed of 6,600 feet per minute, the centrifugal force is 125 pounds and the driving force only eighty-eight pounds, transmitting 17·6 horse-power.

On reflection it is evident, that as the speeds are increased the centrifugal force increases, and the effective tension must be reduced to avoid overstraining the ropes. At a speed of about 4,800 feet per minute the ropes attain their greatest efficiency, *i. e.*, they will transmit more power with the assumed working strain than at any other speed, either higher or lower, although there is but little variation in the power transmitted at that speed and

the power transmitted at either 4,200 feet per minute or 5,400 feet per minute, thus giving a wide range from which to choose. It is well to bear in mind, however, that the higher the speed the greater the wear of the rope, and that for this reason the slower speed is the more economical. All things considered, speeds of from 3,600 to 4,200 feet per minute are best.

It may be well to note, that for the working strain assumed, viz: Three per cent. of the ultimate breaking strain, forty diameters should be regarded as the minimum size of sheaves to be used. If it is necessary to use sheaves of smaller diameter, the working strain should be proportionately reduced; thus in the case previously considered, an inch rope at a speed of 4,500 feet per minute transmitted 18·4 horse-power; now if it is desired to use a 30-inch wheel as a driver, it is advisable to reduce the power transmitted to three-quarters of 18·4, or 13·8 horse-power. This rule does not only apply to the driving and driven wheels, but also to any intermediate idlers around which the rope may be called upon to bend.

The idlers of rope transmissions have usually been made with semi-circular grooves, permitting the ropes to rest upon the bottoms of them. It has been found better, however, in practice to use the V-shaped groove for all purposes, as it insures a revolution of the idlers at the same speed at which the rope is travelling, and thus prevents the wear due to the slipping of the rope in the grooves of the wheel. It has been shown, that idlers having semi-circular grooves in them become highly polished, while those having V-shaped grooves do not. Thus the demonstration that the ropes slip to a certain extent in passing over idlers with the semi-circular grooves, is complete.

The use of the tension carriage in the "American" system of rope transmissions is twofold. In the first place where a continuous rope is used passing over the grooves of two sheaves, it is obvious that the rope must be wound spirally around the two wheels, and that unless the rope in passing off the last groove of one of the wheels is not conducted back again to the first groove of the wheel, the drive would

become inoperative, from the fact that all of the wraps of the rope would soon run off and leave the wheels without connection between them. In order to make this return, the wheel of the tension carriage is set at an angle so as to enable it to make the proper return of the rope. Secondly, the tension carriage is weighted so as to give the proper tension to the rope and serve as a corrective agent to the trifling inequalities that may exist in the sheaves or in the rope. It is by the weighting of the tension carriage that we are enabled to tell the exact amount of strain to which we are subjecting a rope. I might add, that the tension carriage being mounted on guides, it is capable of maintaining the proper tension of the rope even if the latter becomes considerably elongated by the strain put upon it or is variable in its length, due to atmospheric changes. This latter is especially noticeable in rope transmissions which are used wholly, or in part, out of doors, they being subjected to the action of rainy and dry weather.

The use of wire rope for the transmission of power I will only briefly touch upon, by stating that the economic use of it seems to be confined to transmissions of great length between centres. The sheaves employed have to be of very large diameter; otherwise the rope becomes crystallized and is of short life.

With reference to raw hide I might say, that its cost has prevented its general adoption, as it is cheaper to use an increased number of strands of manila rope to accomplish the desired result, though it has one marked advantage, inasmuch as it is possible to use it on sheaves of smaller relative diameter than in cases where manila rope is employed.

If possible, in running the rope care should be taken to have the bends all in one direction; as a rope bent in opposite directions will wear with much greater rapidity.

THE CHEMICAL SECTION

OF THE

FRANKLIN INSTITUTE.

[*Proceedings of the stated meeting held Tuesday, May 16, 1893.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, May 16, 1893.

Dr. WM. H. GREENE, President, in the chair.

A letter from Mr. F. A. Genth, Jr., acknowledging the receipt of the memoir of the late Dr. F. A. Genth, was read, and in response to a question contained therein relative to the embodiment of the Section's memoir in another to be prepared by the family, it was voted that the paper could be used in any way desired by the relatives of the deceased.

On motion of Dr. Hall it was voted that the *Zeitschrift für Anorganische Chemie* be added to the list of journals subscribed for by the Section.

Dr. Tuttle read a paper on "a process of treating mixtures containing sulphides of precious metals and copper." After the conclusion of the paper he called attention to the patented process of dissolving gold, etc., in a dilute solution of potassium cyanide. An animated and interesting discussion of the questions treated of by the author followed, and was participated in by Dr. Keller, Dr. Hall, Mr. Pemberton, Dr. Greene and Mr. Phillips. The paper was referred for publication.

Dr. Tuttle suggested as a good subject for investigation the action of sodium sulphide on silver in presence of water entirely freed from dissolved oxygen, with a view to detecting hydrogen, which, under the circumstances named, should be evolved if the usual action of a solution of sodium sulphide on silver takes place.

Professor Smith then read a paper by himself and Mr. Victor Lenher on "the action of ammonia gas upon molybdenylchloride." The paper was briefly discussed by the author and Dr. Tuttle and was referred for publication.

Dr. Wahl called attention to some samples of an abrasive material known as carborundum, made by subjecting a mixture of silica and coke to the heat of an electrical furnace. The material is a good substitute for emery and corundum, and even for diamond dust in polishing diamonds.

Dr. Keller followed with a conference on "Recent Contributions to our Knowledge of Metallic Reducing Agents." The subject was most admirably presented and called forth a vote of thanks. It was referred for publication in the *Journal*.

The Section then adjourned.

WM. C. DAY, *Secretary*.

A MEMOIR OF FREDERICK AUGUSTUS GENTH.*

FREDERICK AUGUSTUS GENTH was born May 17, 1820, at Waechersbach, in Hesse-Cassel, where his father occupied the position of "Forstmeister" to Prince Isenburg. He received his early training in the gymnasium at Hanau. His university studies began at Heidelberg. While there, although he exhibited much interest in mineralogical and chemical studies, and made frequent botanical and geological excursions, he does not appear to have definitely decided upon his future career. His earliest papers, which he published in 1842, while still a student, in Leonhard-Bronn's *Jahrbuch*, were upon subjects having reference to conchology, geology and mineralogy.

From Heidelberg he proceeded to Giessen, where the fame of that greatest of all teachers of chemistry, Liebig, was attracting students from all parts of the civilized world. There were assembled around this master many men whose names have since become illustrious in chemistry.

When Genth entered the Giessen laboratory, he met among others the two assistants, Fresenius and Will, and as fellow-students with such men as Hofmann, Wurtz, Strecker and Varrentrapp.

The master mind of the head of the laboratory and the scientific atmosphere of the place, had doubtless a great influence upon the young student, and gave his studies a definite direction; but it was under the guidance of Fresenius that he began his chemical exercises. In later years, Genth was wont to express his indebtedness to this great analyst for having laid the foundation of what was later to become the field of his principal scientific work.

At the same time, however, he continued zealously to cultivate the mineralogical studies, and he seems to have given special attention also to crystallography. * * *

* Report of a Special Committee of the Chemical Section. Read and accepted at the stated meeting held March 21, 1893.

Under Liebig's direction he made and published a chemical investigation of a new resinous body, which was given the name of masopin.

In 1843, he went to complete his university studies with Bunsen at Marburg. This eminent savant also had surrounded himself at this time with a circle of students, many of whom afterwards became famous. Among these appear the names of Kolbe, Frankland and Tyndall.

For three years he acted as Bunsen's assistant. His contributions to science during that time were numerous: a few of these related to geology, most of them, however, were on mineral-analytical subjects. The most important of the latter was an investigation of the metallurgical process of the Friedrichshütte near Riechelsdorf.

The results of this well-known research were embodied in the dissertation, which, in 1846, he submitted to the Philosophical Faculty of Marburg, which conferred upon him the degree of Doctor of Philosophy, after he had passed the required examination with high honors. * * *

In the following year, 1848, having meantime married, Genth came to this country. He took up his residence in Philadelphia, and here established an analytical laboratory. Most of his time was taken up with commercial work and with the instruction of young men. His leisure he devoted to original research. Thus he was occupied for more than twenty years.

In this time not less than fifty-six contributions from his pen have appeared, with notable regularity, in various scientific journals. His earlier papers appeared in Keller & Tiedemann's *Nordamerikanischer Monatsbericht* and the *Proceedings* of the Academy of Natural Sciences. His later work was published in the *American Journal of Science*, and several important communications appear in the *Journal of the Franklin Institute*.

He held, for many years, the post of chemist to the State Board of Agriculture of Pennsylvania, being the first to be elected to this office, and practically controlled the fertilizer trade of this State. One of the most prominent specialists in this branch of manufacture bears testimony that his

official work was always regarded as being absolutely reliable. This position he held until the recent establishment of the Agricultural Experiment Station in connection with the State College, to which was transferred the conduct of all researches in the interests of agriculture.

He was also, for a number of years, mineralogist to the Second Geological Survey of Pennsylvania.

In 1872, he was elected to the chair of chemistry and mineralogy at the University of Pennsylvania. This position he held until 1888, when differences with the administration caused his withdrawal.

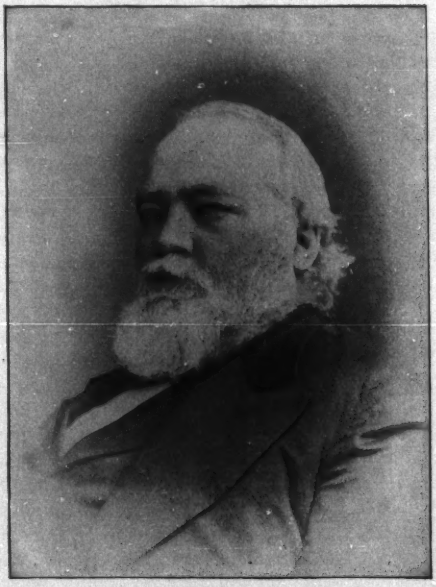
He was the recipient of many evidences of appreciation of his scientific work. He was a member of the National Academy, President of the American Chemical Society, and Honorary Fellow of the American Association for the Advancement of Science. For many years he was an active member of the Academy of Natural Sciences and of the Franklin Institute. He was an honorary member of our Section.

Notwithstanding the distractions of commercial work, to which he was compelled to devote much of his time, and, later on, those of a laborious professorship, he was able, thanks to his unflagging scientific enthusiasm and enormous capacity for work, to contribute more than one hundred papers embodying the results of his personal observations and researches during his professional career of about half a century.

In placing an estimate upon the scientific career of the subject of this memoir, it is not too much to say that he was one of the ablest mineralogists, and certainly the foremost mineral analyst this country has known.

His scientific labors embrace mineralogical, geological and chemical subjects, but valuable as are the results of his chemical researches, his fame will rest chiefly upon the contributions he has made to our knowledge of the minerals of this country. His name appears on almost every page of the records of mineralogy.

His innumerable observations and his careful analyses have helped to throw light upon every class of mineral



FREDERICK AUGUSTUS GENTH.

(1820–1893.)

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species. Of the more than one score of well-established species which he added to the list of our minerals, we need only mention a few, such as nickel gymnite (named genthite by Dana), whitneyite, cosalite, coloradoite, psittacinite, aguilarite, calaverite, lansfordite and nesquehonite; but he deserves no less credit for the elimination of doubtful species and the characterization of others that had been imperfectly described.

In connection with his work in this direction, we should not omit to notice the elimination of owenite, harrisite, coracite, cherokine, and Endlich's schirmirite, and his characterization of roscolite, hiddenite and herderite. His most important contribution to mineralogy is probably his monograph on *Corundum: Its Alterations and its Associated Minerals.* His ingenious interpretation of the metamorphoses exhibited by this mineral, upon which, as well as his numerous careful analyses, his conclusions as to the character of the alterative operations of nature were based, have now been generally accepted by mineralogists and geologists.

His preliminary report, on the mineralogy of Pennsylvania, is an invaluable guide to the mineral history of the State, and the same may be said of his report on the minerals of North Carolina.

His contributions to chemistry proper are less numerous, though some are of considerable importance. In this category undoubtedly must be placed his famous discovery of the "Ammonia-Cobalt Bases," the credit of which, certainly belongs to him, notwithstanding the almost simultaneous announcement of those compounds by Claudet and Frèmy. The joint investigation of these compounds by Gibbs and Genth is a classic research.

His much-quoted paper, on "The Metallurgical Process of the Friederichshütte," is replete with interesting results, notable among which is the discovery of an allotropic form of oxide of nickel contained in the metallic copper. Familiar to all the analytical fraternity is his method of analyzing chrome iron ore and his method of determining copper as oxide.

As a teacher Genth possessed, in a remarkable degree, the ability to impart knowledge. His method consisted substantially in inducing the student to cultivate the habit of close observation and reasoning rather than that of committing facts to memory. Many of his students have attained to positions of distinction, and will be able worthily to perpetuate his fame.

The personal character of the man could almost be predicted by those who never enjoyed the privilege of his acquaintance and friendship, from the sterling character of his scientific work.

He had in full measure the typical characteristic of the German nature, in his love for thoroughness and contempt for superficiality and sham. He was unaffected in manner, and though at times he may have exhibited a certain brusqueness even towards his friends and intimates, this eccentricity served only to attach them more closely to him. To them he was thoroughly devoted, and those who knew him best loved him most. His friendly interest in young men about beginning a scientific career exhibited one of the most charming traits of his nature, and the writers of these inadequate lines which they affectionately dedicate to his memory, gratefully recall from earlier days, the acts of considerate kindness and words of encouragement of the revered master whose life work is done.

His private life was blameless, and in his domestic relations, which were most happy, he was a devoted husband and father. He was twice married, and three sons and five daughters survive him.

WM. H. WAHL,
HARRY F. KELLER,
T. R. WOLF,
Committee.

A NEW METHOD OF REDUCING METALLIC OXIDES.

BY WM. H. GREENE AND WM. H. WAHL.

[*Read at the stated meeting of the Chemical Section, held Tuesday, March 21, 1893.*]

In a previous paper by ourselves, presented at the January meeting of the Section, we gave an account of the various methods that have been proposed for the production of metallic manganese, and described a method which we had devised for the production of this metal, and which we believe to be adapted for commercial use, based on the reduction of one of the lower oxides of manganese by means of aluminum.

In the search for commercially available reducing agents applicable to the solution of the manganese problem we gave consideration to all the elements of which the known thermo-chemical data gave us reason to hope for an exothermic reaction with the oxides of manganese.

Among these silicon did not escape our observation, inasmuch as the heat of formation of its oxide SiO_2, according to the most reliable estimates, is sufficiently greater than that of 2MnO to permit us to expect that the desired reaction should take place.

The references in the literature of chemistry to the reducing action of silicon are not numerous. The only investigations that appear to have a direct bearing thereon are those of Gore,* who makes the observation that "crystals of silicon thrown upon melted argentic fluoride become red hot, undergo rapid combustion, forming fluoride of silicon and depositing silver." By adding crystals of silicon to melted black oxide of copper, the same author† observed a sudden incandescence which raised the temperature to full white heat; copper was also deposited and melted to a red

* *Chemical News*, **29**, 291.

† Gore, *The Art of Electro-metallurgy* (1877), p. 220.

metallic bead and could be hammered to a thin sheet. He noted also that crystals of silicon immersed in a solution of fluoride of copper, containing free hydrofluoric acid, instantly coat themselves with bright copper, and that when silicon is thrown into melted fluoride of sodium, bubbles of vapor are evolved which explode and burn with a yellow flame at the surface of the liquid. The silicon was found subsequently to have lost in weight.

More recently Warren* has published an account of a number of instructive experiments, which strikingly illustrate the energetic reducing properties of silicon. He notes the fact that metallic silicon, though a very stable and inert substance, yet when in admixture with a large number of metallic oxides, becomes at once oxidized, the oxide in admixture with the same becoming itself reduced. Litharge, for example, when mixed in excess with silicon and heated to dull redness, becomes reduced to metallic lead. With copper and all other readily reducible oxides, either a silicide, or, when the oxide is in excess, the pure metal is obtained. He observes that even the oxides of chromium, tungsten and molybdenum are reduced to the metallic state when heated with silicon.

The fact that silicon in the elementary form can only be obtained by indirect and costly methods, rendered any serious consideration of its availability for our purpose out of the question. The thought presented itself, however, that compounds of silicon might possibly be found to answer our purpose, and a very slight consideration of the subject encouraged us to believe that in the metallic silicides we had at hand a ready means of utilizing the chemical energy of one of the most powerful reducing agents.

It appeared reasonable to conclude also that the reducing power of such silicides might be found serviceable not only in the reduction of the oxides of manganese, but also in the reduction of many other metallic oxides.

Certain facts in connection with the metallurgy of steel and copper when given their proper interpretation appeared

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* Warren, *Chemical News*, 65, 75.

to strengthen this view. Thus, in one of the modifications of the open-hearth process of steel making, in which pig iron and scrap are melted on the hearth in contact with oxides of iron, not only the greater part of the carbon but also practically all of the silicon which is invariably present in small proportion is eliminated from the resulting steel, by the reaction with the oxides of iron, and finds its way into the slag as silicate.

Also, in the commercial operations of reduction, remelting and casting of certain metals and alloys, serious practical difficulties arise from the formation or retention therein of small quantities of oxide which have an unfavorable influence upon the strength, ductility and other desirable properties of the metals and alloys, and often render it troublesome to roll them or to obtain sound castings from them.

To counteract such difficulties, compounds in which silicon is present have come into use, either for the purpose of prevention or correction. We may refer as illustrations to the use of ferro-silicon in foundry practice and in the open-hearth process, and to the suggested use of copper, tin and zinc silicides to copper, tin and zinc and their alloys, all for the same general purpose of insuring the production of homogeneous metal and sound castings. In these cases the utility of the silicon appeared to us to be due manifestly to its energetic reducing action on the minute quantities of oxides retained in the molten metal, and to be strictly comparable to the action of phosphorus, magnesium, manganese, aluminum and other energetic reducing agents employed in the purification or refining of metals from small quantities of retained oxides.

Having satisfied ourselves from preliminary considerations of this nature that the use of silicon in the form of the metallic silicides might hopefully be applied as the basis of a commercial method for the reduction of oxidized ores of the metals, we proceeded at the first opportunity to make a number of experiments to test the correctness of our reasoning.

The requirements of iron founders and steel makers, we found, had caused a considerable demand for pig irons con-

taining relatively high proportions of silicon. These are known to the trade as ferro-silicon, silico-spiegel and silico-ferro-manganese, the last two being so designated from their manganese content. These products may be described as silicides of iron, or of iron and manganese, containing from five to thirty per cent. of silicon, and a relatively low percentage of carbon. These silicides seemed adapted to our purpose.

We will confine ourselves here, for convenience, to the description of our method as applied to the production of ferro-alloys. It is obvious that in the production of such alloys, which, if useful at all, will find their principal application in the manufacture of special steels, the presence of carbon in notable proportion will be highly detrimental.

For this reason we require for our purpose a silicide containing as high a proportion of silicon and as low a proportion of carbon as possible. Silicon irons and spiegels containing as high as fifteen per cent. or twenty per cent. of silicon and with carbon not exceeding one per cent. can readily be obtained, and, as we are assured, by special selection of ores and fluxes, can be supplied on demand even higher in silicon than the figures just named. It is interesting also to note the fact that, as a rule, the quantity of carbon, in such silicides, varies with the silicon in an inverse ratio, the carbon decreasing as the silicon increases, and *vice versa*.

We may fully illustrate our method by describing its application to the production of a ferro-manganese; the object in view being substantially the manufacture directly from the oxide of a ferro-alloy sufficiently high in manganese and at the same time sufficiently low in carbon that it may be employed with economic advantage in the production of manganese steel, the deoxidation of the charge in the Bessemer converter, or on the open hearth.

The possible utility of the method may most strikingly be illustrated with reference to the ultimate production of manganese steel, an alloy that is known to possess certain unique and highly desirable qualities, but which presents certain practical difficulties in its manufacture in large quantities which thus far have proved to be troublesome.

By the way of explanation it should be stated that by the present method of manufacturing this alloy, which consists substantially in the addition of ordinary ferro-manganese to fluid iron, the proportion of manganese that can usefully be introduced into the steel is rigorously limited by the carbon, which to the amount of 5 to 6 per cent. is present in the ferro-manganese and which cannot be eliminated therefrom because of its affinity for manganese.

With this explanatory comment we proceed to describe the production of a ferro-manganese by the method which we propose. The chemistry of the operation is extremely simple. When a ferro-silicon (or other silicide) is heated in any suitable furnace chamber (which for our purpose is preferably lined with basic material, such as lime or magnesia) in contact with a metallic oxide (or a mixture of such oxides) and in the presence of a suitable base, such as lime, magnesia, or alumina, the oxygen of the oxides combines with the silicon forming silica, which at once unites with the base to form a more or less fusible silicate that separates as slag, while the metals set free combine to form an alloy.

The mode of our procedure is, precisely stated, as follows: We select a ferro-silicon or silico-spiegel adapted for our purpose and melt the same on the hearth of a furnace, or in a crucible. Then the manganese monoxide (or the proto-sesqui oxide) with which a fluxing material has been incorporated is added in proper quantity. The reaction takes place promptly, the silicon of the ferro-silicon seizes upon the oxygen of the manganese ore, and is thereby converted into silicic oxide which forms with the flux a liquid slag, while the manganese set free by the reduction of the ore combines with the molten iron set free from the silicide. The whole charge of manganese and flux may be added to the ferro-silicon at once, or the addition may be made by portions until a sufficient quantity of the oxide has been employed to utilize the reducing power of all of the silicon that was present in the ferro-silicon, thus reducing a chemically equivalent quantity of manganese oxide to the metallic state.

Assuming that we operate with a silicide containing iron

88 per cent., silicon 10 per cent., carbon 1 per cent. The reaction for simplicity's sake may be supposed to take place according to the equation

$$2\ MnO + Si = SiO_2 + 2\ Mn.$$

We would then employ silicide and manganese oxide in quantities that satisfy the above proportions, *i. e.*, for every 28 parts of silicon in the silicide 142 parts of manganese monoxide and a quantity of lime, manganese or alumina, or a mixture of these that will completely combine with the silicate to form a fusible silicate.

It is necessary, of course, to use a larger quantity of manganese ore than that required by theory, for the reason that a certain quantity of the manganous oxide is always seized upon by the silica and passes into the slag in the form of manganous silicate.

A charge of ferro-silicon (containing 10 per cent. silicon, 1 per cent. carbon) 100 pounds, manganese monoxide 70 pounds, lime 50 pounds, we have found to yield about 128 pounds of a metallic alloy having the composition: iron 70 per cent., manganese 29 per cent., carbon 0·7 per cent., silicon trace.

Assuming that the permissible percentage of carbon in a certain manangese steel is 0·5 per cent., then 100 pounds of a manganiferous alloy of the above composition will produce by mixture with 40 pounds of decarburized iron, 140 pounds of manganese steel of the composition iron 78·8, manganese 20·7, carbon 0·5, silicon trace.

In the preparation of a manganese steel containing the same percentage of carbon by melting decarburized iron with ordinary ferro-manganese containing 80 per cent. manganese and 5·5 per cent. carbon, the resulting metal would contain 92·23 per cent. iron and only 7·27 per cent. manganese. Or, making the comparison on the basis of equivalent quantities of manganese, the manganese steel made from the ordinary ferro-manganese would contain for 20·7 per cent. manganese, 1·4 per cent. carbon; that made by our process would contain for 7·27 per cent. manganese only 0·18 per cent. carbon.

In many cases it is obvious that a metal of the desired composition may be obtained directly by one operation on the furnace hearth. It is probable, for example, that for the production of a manganese steel of a given composition, the required proportions of scrap wrought iron and ferro-silicon of suitable composition could be melted on the hearth, in contact with the manganous oxide.

By procedures substantially like that described, but substituting for the manganous oxide, oxides of nickel, chromium and tungsten, we have succeeded in forming ferro-alloys of nickel (containing as high as 50 per cent. of this metal), chromium (with nearly 20 per cent. of chromium) and tungsten (with more than 50 per cent. of tungsten). With titanium, we have thus far obtained only doubtful results. In all these cases the resulting ferro-alloy is relatively low in carbon, and, as the method we propose does not involve the introduction of carbon either as the reducing agent, or from external sources, the carbon in the product being derived wholly from that which is contained in the ferro-silicon employed in the operation, we have reason to believe that we will be able to produce, on the commercial scale, ferro-alloys with any desired metals so low in carbon as to meet all the requirements of the metallurgical arts.

Thus far our experiments have been confined to the ferro-alloys and have been on the laboratory scale. It will be obvious, however, that the chemical reactions involved will hold good for other classes of alloys, and that alloys of copper, for example, with difficultly-reducible metals, may be obtained quite as readily by fusing the appropriate oxides with copper silicide.

In conclusion, the method which we propose, we believe, will enable the metallurgist advantageously to effect the reduction of numerous metallic oxides without the employment of carbon, and to produce numerous useful and important alloys.

ACTION OF THE HALOID ACIDS, IN GAS FORM UPON MOLYBDIC ACID.

By Edgar F. Smith and Vickers Oberholtzer.

[*Read before the Chemical Section, April 18, 1893.*]

Debray (*Comp. rend.*, xlvi, 1098, and *Annalen der Chemie und Pharmacie*, **108**, 250), first called attention to the fact that a very volatile, crystalline compound of the formula $MoO_3 \cdot 2HCl$ resulted upon exposing molybdic acid, heated from 150–200° C., to the action of hydrochloric acid gas. It is true that the constitution of this volatile product may also be represented by the formula $MoO(OH)_2Cl_2$, which would make it a molybdenum hydroxychloride. Dismissing the question of constitution for the present, and considering the point of ready volatility, it seemed to us that this behavior might be utilized for the separation of molybdic acid from tungstic acid, as the latter apparently does not enter into volatile combination with hydrochloric acid gas. We, therefore, exposed weighed amounts of sublimed molybdic acid to the action of the acid gas and succeeded in expelling the molybdic acid completely from the porcelain boats containing it. Applying the same treatment to what we considered pure tungstic acid, we were greatly surprised to discover that very appreciable quantities of a sublimate, similar in every respect to that of molybdenum hydroxychloride were expelled from the boat. An examination of this product proved it to be the molybdic acid compound. In short, our tungstic acid was not pure. We, however, continued to heat portions of it in hydrochloric acid gas until a sublimate was no longer formed, when on mixing molybdic acid in known amount with the residual tungstic acid, we discovered that we could completely expel the former acid from the latter. Our next step was to observe the effect of heating anhydrous sodium molybdate in hydrochloric acid gas. The appended results show a quantitative conversion

into sodium chloride, consequently a complete volatilization of the molybdic acid:

Na_2MoO_4 in Grams.	NaCl.	NaCl Required.
0·1302 gave at 150–200°, ...	0·0738	0·0739
0·1832, ...	0·1038	0·1040
0·2046, ...	0·1159	0·1162
0·3845, ...	0·2186	0·2183

As we were about to apply this method to the quantitative separation of molybdic and tungstic acids, both present as sodium salts, a closer scrutiny of the existing literature relating to this subject revealed that E. Péchard (*Compt. rend.*, **114**, 173, and *Zeit. f. anorg. Chemie*, **1**, 162) had already carried out the determination of molybdic acid and its separation from tungstic acid in this way with very evident success. Our own experiments confirm those of Péchard in every particular.

As previously observed, the tungstic acid that we thought pure contained molybdic acid. Traube (*Neues Jahrbuch für Mineralogie, Geologie und Paläontologie, Beilageband*, **7**, 232) has demonstrated that natural calcium tungstate, scheelite, and commercial tungstic acid obtained from the mineral wolframite, contain molybdic acid. E. Corleis (*Liebig's Annalen*, **232**, 265), has shown that the latter acid is even present in the "Wolframsaeure puriss" of trade, while Friedheim (*Zeit. f. anorg. Chemie*, **1**, p. 76) asserts that commercial sodium tungstate is strongly contaminated with sodium molybdate, and that even when exercising the greatest care in the process of purification the tungstate continued to show traces of molybdenum.

We found molybdic acid present in the purest sodium tungstate that we could get, and in the minerals scheelite and wolframite, when these were exposed to the action of hydrochloric acid gas at a temperature not exceeding 400° C. Hence, we are disposed to regard this method as excellently adapted for the detection of molybdic acid, as well as for the purification of tungstic acid and tungstates containing molybdenum.

Our original purpose having been the study of the

behavior of molybdic acid in atmospheres of all the gaseous haloid acids, we may now briefly recount our experiences in those directions.

Action of Hydrobromic Acid, in Gas Form, upon Molybdic Acid.—The molybdic acid used by us was purified by converting the commercial acid into the ammonium salt, which was recrystallized a number of times and then ignited with air access. The product was sublimed very carefully from a platinum crucible. The hydrobromic acid was prepared by dropping bromine from a separatory funnel upon crude anthracene contained in a half-litre flask. It passed through a hard-glass tube, six inches in length, filled with anthracene, then through two U-tubes containing a paste of amorphous phosphorus, and two U-tubes provided with fused calcium chloride, while the sixth and last tube contained phosphoric anhydride. Having completed this circuit it was admitted to a perfectly dry combustion tube, into which had been introduced a porcelain boat filled with molybdic acid. The anterior portion of the combustion tube was closed with a calcium chloride tube to exclude all moisture. The heat used in the experiment was supplied from a combustion furnace. An ordinary thermometer was placed above the combustion tube; its bulb rested directly over the boat. In this manner we recorded the approximate temperature at which the reaction took place. As soon as the entire apparatus was filled with the gas, three burners of the furnace, directly under the boat, were lighted, and the heat gradually raised until it reached 200° C. A change took place almost instantly. Just beyond the boat appeared a heavy sublimate, with a color resembling that of potassium permanganate. Beyond this solid a brownish yellow colored liquid separated; on cooling it changed to long, beautiful yellow needles. These proved to be unstable, melting almost immediately when brought in contact with the air. At the expiration of an hour the passage of the hydrobromic acid gas was interrupted. The permanganate colored sublimate was removed from the sides of the tube as completely as possible, introduced into a porcelain boat and then carefully resublimed in a current of dry

carbon dioxide. The compound sublimed in fern-like aggregates, consisting of dark red or purple red, shining, overlapping plates, extending from one side of the combustion tube to the other. They dissolved in water with liberation of heat. Their aqueous solution was colorless, but upon standing became blue in color. The crystals themselves changed in appearance on prolonged exposure to the air. By preserving them in an atmosphere of carbon dioxide they suffered no decomposition. Examined under a polarization microscope they showed their ability to polarize light, and that they consisted of aggregations of perfectly square plates. After the re-sublimation portions of the substance were weighed off in weighing tubes and analyzed. For the bromine determination the material was dissolved in as little cold water as possible, dilute nitric acid added, and this followed immediately with silver nitrate. The resulting silver bromide was treated in the usual manner. In estimating the molybdenum, the substance was brought into a weighed porcelain crucible and dilute nitric acid added. The solution was evaporated almost to dryness at a very gentle heat, when the crucible contents were treated with concentrated nitric acid, after which followed evaporation to perfect dryness. This operation was repeated and a gentle but direct heat applied to the crucible for periods varying from one-half to one hour. This was done to fully oxidize the molybdenum to trioxide. Portions of the new compound were mixed with freshly ignited litharge and heated in a current of dry air, using a perfectly dry combustion tube, provided with a weighed calcium chloride tube. The weight of the latter showed no increase, so that we were safe in considering our substance free from hydrogen.

ANALYSES.

Bromine Determination.

	Ag. Br.		*Bromine percentage.*
0·1334 grams substance gave	0·1793 gr.	=	57·19
0·3353	0·4499 "	=	57·09
0·0680	0·0908 "	=	56·82

The mean of these bromine percentages is 57·037 per cent.

Molybdenum Determination.

	MoO_3.		*Molybdenum percentage.*
0·2545 grams substance gave	0·12865 gr.	=	33·69
0·2916	0·1466 "	=	33·52
0·1115	0·0559 "	=	33·42

The mean of the molybdenum percentages is 33·54 per cent.

We experienced difficulty in wholly eliminating the traces of blue oxide in all of the molybdenum determinations, hence we look upon the results given above as low.

Regarding our compound as consisting of molybdenum, bromine and oxygen with the above percentages, and taking the oxygen by difference, we deduce as the most probable formula MoO_3Br_2, $MoOBr_2$ or $Mo_2O_3Br_4$—molybdenum sesquioxide tetrabromide. The theoretical requirements of this formula are: 34·28 per cent. Mo, 57·19 per cent. Br. and 8·57 per cent. O.

The only existing molybdenum oxybromide until the present has been MoO_3Br_2—molybdenyl bromide, discovered by Blomstrand on passing bromine vapor over the heated dioxide of molybdenum, or by heating a mixture of molybdic acid and boron trioxide with potassium bromide. It is mentioned as forming yellow, deliquescent tablets. For the sake of comparison, we made Blomstrand's compound by the second method. We found that when it was sublimed upon a previously heated portion of the tube it separated in "*mehr ausgebildeten Krystalltafeln auf; bei rascher Sublimirung in undeutlich krystallinischen Schuppen. Farbe schön gelbroth*" (Blomstrand, *Jour. prk. Chemie*, **82**, 439). Our compound, however, is formed simultaneously with that of Blomstrand when vapors of bromine are conducted over heated molybdic acid; the tube in which this reaction was made was freed from air by conducting bromine vapors through it and heat was not applied until we were satisfied that bromine alone was present.

The brownish-yellow liquid formed at the same time with the purple-red colored solid was crystallized in the tube in which it had been produced; the tube was then severed at a point between the yellow and red-colored com-

pounds. The yellow immediately liquefied on exposure to the air. The liquid was collected in a small and previously weighed beaker; this was then placed in a sulphuric acid desiccator and the air exhausted. At the expiration of from two to three days the yellow needles had re-formed. The beaker and its contents were then rapidly weighed. Water was poured on the needles; their solution was colorless or slightly yellow tinged. On standing, the liquid slowly acquired a deeper yellow or reddish-yellow hue, and after twenty-four hours a blue oxide of molybdenum had separated.

The bromine and molybdenum of this product were determined in the same manner as in the purple-colored solid. We, however, had no difficulty in obtaining perfectly white molybdic acid in all the determinations that follow:

ANALYSES.

Bromine Determination.

	Silver Bromide.		*Bromine percentage.*
0·0950 grams substance gave	0·1403 gr.	=	62·83
0·2523	0·3700 "	=	62·50
0·2709	0·3967 "	=	62·37
0·0250	0·0365 "	=	62·12

The mean percentage equals 62·45 per cent.

Molybdenum Determination.

	MoO_3.		*Percentage of Mo.*
0·0946 grams substance gave	·0346 gr.	=	24·39
0·0946	·0337 "	=	23·75
0·1892	·0686 "	=	24·06

The mean of these percentages is 24·03 per cent. The formula we deduce from these results is $MoO_3 \cdot 3HBr$; it perhaps might be better represented as a trihydroxybromide $MoO(OH)_3Br_3$. The theoretical requirements are 62·02 per cent. Br and 24·80 per cent. Mo.

It is interesting to note that the long, yellow-colored needles of this compound were also obtained upon passing hydrobromic acid gas over the oxybromide of Blomstrand at a gentle heat. This change may easily be conceived as

occurring if we grant the presence or production of water through the formation of secondary products.

$$MoO_2Br_2 + H_2O + HBr = MoO_3 \cdot 3HBr.$$

As we were not in a position to ascertain the true composition of the individual substance or substances from scarcity of material, we offer the above suggestion as a possible explanation for the appearance of the hydroxybromide in the manner just indicated.

Action of Hydriodic Acid, in Gas Form, upon Molybdic Acid.—A violent reaction occurred, in the cold upon passing the dry acid gas over molybdic acid; much heat was evolved, and iodine was liberated. The non-volatile product that remained in the boat possessed a bright violet color. It was exposed for a period of two hours to a temperature ranging from 45–50° C., during which time a continuous stream of dry and pure gas was conducted over it. Carbon dioxide was next introduced and passed for an equal period, while the temperature was maintained at 50° C. The results obtained from many analyses of this product pointed to the probable composition MoO_3HI, but as the quantity of iodine varied according to the length of time during which the hydriodic acid gas acted and with the temperature, we feel unable to assign any definite composition to the compound. It has seemed to us, from a careful study of the experimental results, that several derivatives were formed, but we were unable to separate them, and indeed by continuing the action of the gas for periods varying from six to eight hours, at the same time elevating the temperature from 105 to 120° C., iodine continued to separate. At last a violet-blue colored product remained; this appeared to be homogeneous. Prolonged action of the gas was without further reduction, therefore carbon dioxide was introduced to expel it. The blue colored product suffered no change on exposure to the air. We obtained what appeared to be the same substance by exposing the iodine-containing compound mentioned above to a temperature of 200° C., in an atmosphere of carbon dioxide. Indeed, mere exposure of the iodine compound to the air for some time gave the blue-colored derivative.

The same form of apparatus was used here that we have described with the oxybromides. The hydriodic acid gas was made from moist phosphorus and iodine. It was carefully dried.

Analyses.—An analysis of the blue-colored residue resulted as follows: The molybdenum was determined as under the bromine derivatives:

	Mo_3O.	Mo Per Cent.
0·1099 grams substance gave	0·1053 gr.	= 64·19
0·1017	0·0972 "	= 63·72
0·0807	0·0775 "	= 64·02
0·0959	0·0937 "	= 64·92
0·1386	0·1350 "	= 64·93

The mean molybdenum percentage is therefore 64·35 per cent.

Water Determination.

	H_2O	Per Cent.
0·1533 grams substance gave	·0138 gr.	= 9·00
0·1673	·0142 "	= 8·49

The mean of these percentages would therefore be 8·74 per cent. An intense red heat was required to fully expel this water content. The figures obtained would lead to an oxide of the formula $Mo_4O_{10},3H_2O$; this would require 64·21 per cent. Mo and 9·03 per cent. H_2O. Iodine was not found in the compound. The dehydrated residue was brown in color. Three determinations of its molybdenum content indicated it to be Mo_2O_5. As a result then of the action of hydriodic acid gas upon molybdic acid we can point to no definitely iodated product, but to a blue oxide, a product of reduction. In this connection we may direct attention to the observation of Schulze (*Journ. prk. Ch.* (N. F.), **29**, 440) that molybdic acid sustains reduction when heated with potassium iodide, air being excluded. The resulting products possess variable composition, but by the use of four parts of molybdic acid and one part of potassium iodide a definite product was prepared. It proved to be a new oxide of molybdenum, steel blue in color, crystalline and possessing metallic lustre. Its analysis gave results agreeing with the formula Mo_4O_{11}. Our reduction product is quite analogous to this, except that it is hydrous.

Action of Hydrofluoric Acid, in Gas Form, upon Molybdic Acid.—The hydrofluoric acid gas was evolved from fluorspar and sulphuric acid. It passed directly over the molybdic acid contained in a platinum boat and the latter in a platinum combustion tube from which a delivery tube led into a platinum flask, cooled by ice water. At a temperature ranging from 300–400° C., all the molybdic acid was converted into a volatile product that collected upon the anterior portions of the platinum combustion tube in crystals, having a peculiar red color. On holding the tube in which these crystals had been sublimed toward the light, it appeared to be filled with violet vapors of iodine; this was, however, due to reflection of light from the sides of the flat needle-like crystals. It is scarcely necessary to remark that before disconnecting the apparatus, carbon dioxide was conducted through it to expel the hydrofluoric acid. The platinum flask also contained the volatile molybdenum product. Much hydrofluoric acid was with it. This was expelled by the introduction of the carbon dioxide.

The new product when removed from the vessels containing it was found to be deliquescent, and it gradually decomposed into a blue oxide of molybdenum. It attacked glass, was insoluble or nearly insoluble in water, but dissolved to a colorless liquid in hydrofluoric acid. Portions of it were weighed off as rapidly as possible in platinum crucibles, and the molybdenum determined as trioxide by evaporation with nitric acid, followed by gentle ignition.

Molybdenum Determination.

	MoO_3.	Mo. Per Cent.
0·0526 grams substance gave, ...	0·0479 gr.	= 60·70
0·1066	0·0967 "	= 60·66
0·1166	0·1051 "	= 60·94
0·1265	0·1164 "	= 61·35

The mean of these determinations is 60·91 per cent. Mo. Formed in the same manner as molybdenum sesquioxide tetrabromide, we find that these results agree very closely with an oxyfluoride of analogous formula $Mo_2O_3Fl_4$, which would require 60·76 per cent. Mo. In experimenting with

the above oxyfluoride we several times observed a slight quantity of a colorless liquid, which upon careful evaporation with nitric acid left a very appreciable quantity of molybdic acid. It may, perhaps, be an analogue of the very volatile $MoO_3 \cdot 2HCl$, and the unstable, liquid $MoO_3 \cdot 3HBr$. We endeavored to fix its composition, but experienced so great difficulty in getting material that we could safely consider sufficiently pure that we abandoned it entirely. The work attending its preparation is anything but pleasant and the yield exceedingly uncertain.

But one other oxyfluoride of molybdenum is known; namely, that prepared by Schulze (*Jour. prk. Chemie* (N. F.), **21**, 442), by fusing metallic fluorides together with molybdic acid with the exclusion of air. It has the constitution represented by the formula MoO_2Fl_2.

Reviewing the action of the gaseous haloid acids upon molybdic acid we observe:

(1) That hydrochloric acid gas converts the acid into a solid, very volatile product $MoO_3 \cdot 2HCl$.

(2) That hydrobromic acid changes molybdic acid to a volatile brownish-yellow liquid, $MoO_3 \cdot 3HBr$, forming long yellow needles at low temperatures and under diminished pressure, as well as a beautifully crystallized solid of the formula $Mo_2O_3Br_4$.

(3) That hydriodic acid reduces molybdic acid to a new oxide $Mo_4O_{10} \cdot 3H_2O$.

(4) That hydrofluoric acid converts the molybdic acid into at least one well-formed but volatile product, having the constitution represented by the formula $Mo_2O_3Fl_4$.

Püttbach (*Annalen*, **201**, 137) divides the known molybdenum oxychlorides into two classes:

Saturated.	*Unsaturated.*
$MoOCl_4$	$Mo_2O_3Cl_7$
$Mo_2O_3Cl_6$	
$Mo_2O_5Cl_8$	$Mo_2O_3Cl_4$
MoO_2Cl_2	

But one oxybromide is known. Its formula is MoO_2Br_2. Our experiments add to this, the compound $Mo_2O_3Br_4$, which

would correspond to $Mo_2O_3Cl_4$. The latter is light brown in color, while the former possesses a deep purple color. Schulze's oxyfluoride would correspond to MoO_2Cl_2 and MoO_2Br_2, while that obtained by us corresponds to $Mo_2O_3Cl_4$ and $Mo_2O_3Br_4$. Püttbach's division presupposes the presence of a sexivalent molybdenum atom in the saturated members, while the unsaturated are regarded as derived from two molecules of $MoCl_5$ by the substitution of oxygen for equivalent amounts of chlorine. Our oxybromide, $Mo_2O_3Br_4$, and oxyfluoride, $Mo_2O_3Fl_4$, may be looked upon as possessing similar origin, although their corresponding pentabromide and pentafluoride are unknown. The compound $MoO_3 \cdot 3HBr$, like $MoO_3 2HCl$, presupposes the presence of a sexivalent molybdenum atom and may be properly considered a hydroxybromide, represented by the formula $Mo(OH)_3Br_3$, a derivative of the unknown hexabromide $MoBr_6$.

CHEMICAL LABORATORY OF THE
UNIVERSITY OF PENNSYLVANIA, APRIL 15, 1893.

THE ELECTRICAL SECTION

OF THE

FRANKLIN INSTITUTE.

[*Proceedings of the stated meeting, held Tuesday, April 25, 1892.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 25, 1893.

Mr. E. G. WILLYOUNG, President in the chair.

The stated meeting of the Section was called to order by the President at 8.10 P.M. There were present fifty-seven members and visitors. The minutes of the previous meeting were read and approved. The treasurer reported a balance of $36.91 in the treasury, and presented bills amounting to $10.32, which were ordered paid.

The meeting was then informally adjourned to allow the members to see the working of the telautograph, the recently perfected invention of Prof. Elisha Gray. The meeting was called to order again at 9.15. A committee, composed of Prof. E. J. Houston and the President, was appointed to endeavor to secure Prof. Elihu Thomson to show before the Electrical Section some results of his most recent work.

The President and Mr. Carl Hering were appointed a committee to provide for lunches at the next two meetings.

Mr. C. Billberg presented two curves taken from one of his sixty-five horse-power motors, illustrating the influence of the iron wire wound over the whole surface of the armature. The one was platted from a test before the iron wire was put on, and the other after, the latter showing a gain of about ten to eleven per cent. in E. M. F., with the armature making in both cases 665 revolutions per second, and having the same field excitation.

Mr. Willyoung showed some interesting experiments with Crookes tubes.

The paper, by Messrs. Willyoung and Northrup, on "Some Methods of Varying the Sensibility of Galvanometers," was referred for publication.

The meeting then adjourned.

R. H. LAIRD, *Secretary*.

BOOKS RECEIVED.

[In sending books for notice in the *Journal*, publishers are requested, for the information of the reader, as well as for their own advantage, to give the price. This announcement by title will be followed, in most cases, by a review, which will appear at the earliest opportunity.]

Adriance, J. S. Laboratory Calculations. New York: John Wiley & Sons. 1893. 12mo.

Alheilig. Corderie. Cordages en Chanvre et en Fils Métalliques. Paris: Gauthier-Villars et fils and G. Masson. 12mo. Price, 3 francs.

Army and Navy Journal Manual of Guard Duty. New York: Army and Navy Journal. 1893. 32mo.

Bedell F. and A. B. Crehore. Alternating Currents. New York: W. J. Johnston Co. 1893. 8vo.

Benjamin, P. The Voltaic Cell: its Construction and its Capacity. New York: John Wiley & Sons. 1893. 8vo. Price, $5.

Bertin, L. E. État Actuel de la Marine de Guerre. Paris: Gauthier-Villars, n. d. 12mo. Price, 3 francs.

Bovey, H. T. Theory of Structures, and Strength of Materials. New York: John Wiley & Sons. 1893. 8vo. Price, $7.50

Brainard, F. R. Knots, Splices, Hitches Bends and Lashings. New York: Practical Publishing Company. 1893. 24mo. Price, $1.

Buberl, J. Bericht des vom Oesterreichen Ingenieur und Architekten-Vereine eingesetzten Comites zur Aufstellung von Typen für Walzen. Vienna: Society. 1892. Price, 5 marks.

Bureau des Longitudes. Annuaire, pour l'an 1893. Paris: Gauthier-Villars et fils. 12mo. Price, 1 franc 50 c.

DeLaunay, L. Formation des Gîtes Métallifères. Paris: Gauthier-Villars et fils and G. Masson. 12mo. Price, 3 francs.

Dixon's American Graphite Pencils. Catalogue and Price-list. Jersey City. 8vo.

Enterprise Mining Company. First annual report. September 30, 1892, with a description of the property. By Leo Von Rosenberg. New York. 1892. 4to.

Foster Engineering Company. Newark N. J. Illustrated Catalogue.

Gilbert, Wm. On the Loadstone and Magnetic Bodies. Translated by P. F. Mottelay. New York: J. Wiley & Sons. 1893. 8vo. Price, $4.

Goodhue, W. F. Municipal Improvements. A Manual of the Methods, Utility and Cost of Public Improvements, for the Municipal Officer. New York: John Wiley & Sons. 1893. 12mo.

Grant, G. B. Treatise on Gear Wheels. Lexington, Mass.: Author. 1893. 8vo. Price, 60 cents.

Grimshaw, R. Engine-room Chat. New York: Practical Publishing Company. 1893. 12mo. Price, $1.

Handy Sketching Book for Engineers and Draftsmen. New York: Spon & Chamberlain. 1893. Price, 25 cents.

Holman. S. W. Discussion of the Precision of Measurements. New York: J. Wiley & Sons. 1892. 12mo. Price, $2.

Houston. E. J. Electrical Measurements. New York: W. J. Johnston & Co. 1893. 12mo.

Infantry Drill Regulations. New York: Army and Navy Journal. 1893. 32mo. Price, 50 cents.

Jean, F. Industrie des cuirs et des peaux. Paris: Gauthier-Villars, n. d. 12mo. Price, 3 francs.

Kapp, G. Alternating Currents of Electricity: their generation, measurements, distribution and application. New York: W. J. Johnston & Co. 1893. 16mo

Koll, O. Die Theorie der Beobachtungsfehler und die Methode der Kleinsten Quadrate mit ihrer Anwendung auf die Geodäsie und die Wassermessungen. Berlin: Jul. Springer. 1893. 8 + 323 + 31 p. O. Price, 10 marks.

Knudson, A. Triangular Surveys from Single Stations. San Francisco. 1892. 24mo.

Langlois, P. Le Lait. Paris: Gauthier-Villars, n. d. 12mo. Price, 3 francs.

Madamet, A. Distribution de la Vapeur. Paris: Gauthier-Villars, n. d. 12mo. Price, 3 francs.

Massachusetts Institute of Technology. Department of Civil Engineering. Boston. 1892. 8vo.

Michie, P. S. and F. S. Harlow. Practical Astronomy. New York: John Wiley & Sons. 1893. 8vo.

The Mineral Industry: its Statistics, Technology and Trade, in the United States and other countries, from the earliest times to the end of 1892. Vol. I. Edited by Richard P. Rothwell. New York: Scientific Publishing Company, 1893. 8vo.

Parker, E. W. Coal. Extract from the "Mineral Resources of the United States." Calendar year. 1891. Washington: Government. 1892. 8vo.

Public Ledger Almanac for 1893. Philadelphia: Geo. W. Childs.

Religious Liberty Library. No. 7. March, 1893. Appeal and Remonstrance. Resolutions adopted by the General Conference of Seventh-Day Adventists. New York: International Religious Liberty Association. 1893. 24 pp. O. Price, 3 cents.

Sanford, F. Some Observations upon the Conductivity of a Copper Wire in Various Dielectrics. Palo Alto: Leland Stanford Junior University. 1892. 8vo. Price, 50 cents.

Standard Thermometer Company. General Catalogue. No. 25. Peabody, Mass. 4to.

Swinburne, J., and C. H. Wordingham. Measurement of Electric Currents. New York: D. Van Nostrand Company. 1893. 24mo. Price, 50 cents.

United States Coast and Geodetic Survey. Determinations of Gravity with Half-second Pendulums on the Pacific Coast, in Alaska and at Washington, D. C., and Hoboken, N. J. By T. C. Mendenhall. Appendix No. 15. Report for 1891. Washington: Government. 1892.

U. S. Navy Department. Annual Report of the Chief of the Bureau of Steam Engineering for the year 1892. Washington: Government. 1892. 8vo.

Viaris, Marquis de. L'Art de Chiffrer et Déchiffrer les Dépêches Secrètes. Paris: Gauthier-Villars, n. d. 12mo. Price, 3 francs.

Wilson, H. M. Manual of Irrigation Engineering. New York: John Wiley & Sons. 1893. 8vo. Price, $4.

BOOK NOTICES.

A Manual of Irrigation Engineering. By Herbert M. Wilson, C.E. 8vo. 352 pp. New York: John Wiley & Sons.

The rapid settlement of the territory west of the 100th meridian, and the great demand for water for irrigation, mining and manufacturing which has been so ably advocated by the Director of the U. S. Geological Survey, has created a demand for more literature bearing on this important subject. Hence, there have appeared recently a number of important publications on this topic, amongst which we note the above work by Mr. Wilson, Member Am. Soc. of Civil Engineers. His aims have been to produce a book of practical use to students and irrigation companies by eliminating ambiguous or complicated hydraulic formulæ and giving descriptions of works actually built and doing good service. In this he has been successful, while in India

irrigation works have been very expensive and have not been a financial success, there are sections of the United States where the conditions are favorable to such enterprises, but they should be carefully considered from the standpoint of the engineer and it is here that the book will be found to be of value, as it gives a table of cost of irrigation in the arid regions of the United States. It treats of rainfall, evaporation, alkali, drainage, sedimentation, measurement quality, dams, wells, storage reservoirs, sluices, flumes and kindred subjects, and is abundantly illustrated with well-selected works in existence.

The "make up" of the press work might, we think, be improved in some instances. (pp. 184–294–320–327.) H.

The Yale and Towne Manufacturing Company Catalogue. No. 14. Locks and Hardware. Stamford, Conn., U. S. A. 1893. With price book.

This catalogue marks a decided innovation in the make-up of such works, in that the practice of using full-sized illustrations is plumply abandoned and the volume thus reduced to reasonable size.

In it is presented for the first time the company's new "paracentric" lock, the peculiarity of which lies in the construction of the keyway "with continuous longitudinal barrier, in planes normal to the plane of motion of the pin tumblers, these barriers projecting from opposite sides of the keyway past its centre line and interlocking so deeply as to practically preclude the use of any picking instrument to vertically operate the tumblers."

The catalogue is a model of thoroughness, excellence of arrangement and typographical beauty, and reflects the highest credit upon the intelligent industry of Mr. H. H. Suplee, the company's editing manager. T.

Photographic Mosaics. An annual record of photographic progress. Edited by Edward L. Wilson. Twenty-ninth year. New York: Edward L. Wilson. 1893 12mo. Price, $1.

Much need not be said of this useful little hand-book. A publication which has been known and used by photographers for twenty-eight years will need no special praise. In the opening article the work in photography during the year 1892 is reviewed by the editor. He also contributes six other papers, on various subjects, which will be of great value in the studio. Dr. E. Liesegang and Dr. J. M. Eder furnish each an article on "Metol."

Leon Vidal, in a short essay, gives us some of his views on the "Direct Reproduction of Colors."

Among other important subjects discussed we select, at random: "A National College of Photography," by C. T. Stuart; "Bromide Paper," by A. R. Dresser; "Thickly Coated Plates," by Chapman Jones; "Reception-room Duties," by M. Phillis Bell.

Another valuable feature is the full-page plates, of which there are more than eighty, reproduced from photographs taken by artists in every part of

the world. They illustrate, better than pages of letter-press, what can be accomplished with a camera reinforced by artistic taste.

The book should be read by every photographer, amateur as well as professional. A. R.

Alternating Currents of Electricity. Their generation, measurement, distribution and application. By Gisbert Kapp, C. E. With an introduction by Wm. Stanley, Jr. 1893. New York: The W. J. Johnston Company, Limited, 41 Park Row. Price, $1.

The rapid development of alternating currents, and the great part they are destined to play in the transmissions of power, have caused an increased interest in the subject, but unfortunately it has heretofore been presented in such a manner as to be beyond the reach of the great body of readers.

In the present work the principles are developed in a simple manner that can be followed by any reader, and the various applications are sketched in a broad and instructive way, that clears away the many mysteries with which they are supposed to be surrounded. The few mathematical formulæ in the book are confined to appendices.

The first four chapters are devoted to explaining alternating currents and their measurements, and the succeeding three chapters are on the principles and design of alternating current machines and transformers. Chapter VIII is on alternating central stations, and Chapter IX on the parallel coupling of alternators.

The remaining chapters, which are particularly valuable, treat of various forms of alternating motors, especial attention being paid to the explanation and discussion of multiphase motors. This difficult subject is treated so clearly that the attentive reader should be enabled to form as clear an idea of these new forms as of the simpler continuous current machines.

The treatment throughout is thoroughly practical, and the data and discussion on the design and construction of apparatus will be found useful and helpful to the electrician and designer. To the student and the general public interested in the subject this work should have a warm welcome, as it brings within their comprehension one of the most important and interesting subjects in applied electricity. W.

Original Papers on Dynamo Machinery and Allied Subjects. By John Hopkinson, M.A., D.Sc., F.R.S. New York: The W. J. Johnston Company, Limited. 1892. 249 pages, 98 illustrations. Price, $1.

This collection includes all the papers on electro-technical subjects published by the distinguished author, several of which have had an important bearing on the advance of electrical science. Perhaps no other contributions to electrical literature since the days of Faraday have been of more importance as those contained in the present volume.

In the first paper that invaluable aid to the study and design of dynamos,

the characteristic curve, was first announced, and the following three papers are devoted to developing its applications.

The fourth and fifth papers, on the theory and design of continuous current dynamos, furnished the fundamental principles upon which the design of such dynamos is now based.

The sixth paper established the important principles in regard to coupling alternating current machines; the next three papers are on the transformer, and the remaining two are on the "Theory of the Alternate Current Dynamo and Electric Light Houses," respectively.

These papers, with the authorization of Dr. Hopkinson, are for the first time published in a collected form and rendered accessible to the general public, and they should furnish a fruitful source of inspiration to those in search of knowledge at first hand. W.

How to Become an Engineer. By George W. Plympton. Van Nostrand Science Series. No. 100. New York: D. Van Nostrand Company. 218 pp. Price, 50 cents.

The work defines the various classes of engineers, military, civil, mining, electrical, hydraulic, sanitary and mechanical. It gives extracts from distinguished authors relative to the profession and the curriculum of the Rensselaer Polytechnic School, closing the second chapter on the thirty-second page, with the remark that "other institutions in this country, affording similar courses of study, are Cornell University, Princeton College, Rutgers College, Lehigh University, Stevens Institute, Polytechnic Institute of Brooklyn and Michigan University."

In this limited test of American institutions it is to be observed that with the exception of the University of Michigan and Cornell, they are all within fifty miles of New York City; their curricula are very dissimilar and some of the most prominent technical schools of the United States are not even referred to, notably Columbia School of Mines and the Massachusetts Institute of Technology.

If the object of the book was to guide a young man in the preparation for or selection of an engineering profession, the data furnished are certainly very meagre and unsatisfactory so far as they apply to the American youth.

It is safe to say that the majority of the applicants for such information is to be found amongst those who have not had special advantages in the way of general preparatory or culture studies, but who are artisans, and who can only pursue their studies at night and to them an outline of a simple course, giving the names of books to be consulted and occasional hints as to applications would be of value.

The remainder of the work is a description of foreign methods, not specially applicable here, but even in this part of the book we regret to find statements which hardly represent the present methods, *e. g.*, the apprentice systems of a few decades ago are giving place in England to the regular technical school, some of which the author mentions in his syllabus. The work closes with extracts from addresses and reports, compiled from various sources, and although it contains much material which is of interest

to instructors and teachers, it does not seem to answer the query propounded in its title so far as it applies to the American youth in a very satisfactory manner. It has, however, the merit of showing that to attain eminence in the profession requires many years of general and special training for which comparatively few have either the time or the means to spare, and it would be a valuable addendum if the writer would give a symposium of the results attained by those who started in the race. H.

Engineers' Surveying Instruments: Their Construction, Adjustment and Use, By Prof. Isa O. Baker, University of Illinois. New York: John Wiley & Sons. 8vo. 386 pp.

The title of this work sufficiently explains its scope, which includes all of the ordinary instruments used in the various kinds of surveys, with the notable exception of the sextant. This omission is important when it is considered that a good pocket sextant is a substitute for many other less portable instruments. The recent use of the camera also as a valuable aid in topographical work should not be ignored. The subject is treated with Professor Baker's usual perspicuity; is clear and full; with illustrations, tables, forms for notes and examples. There is one point upon which more stress might have been laid, viz: the practical value of the limits of errors; or, in other words, the relation of the scale and the instruments in determining how much care and time should be expended in collecting data for different kinds of work, and the consequent organization of the corps. A few words on the relative accuracy and cost of the different methods would also add to the utility of the work.

It follows from the omission of the sextant that there is no reference to hydrographic surveys, or to the location of drainage systems, etc., and the Appendices on Elimination of Local Attraction, Computing Areas by Traversing, Probable Error and Problem in Testing, etc., seem to be out of place, as if they were afterthoughts. Each has its appropriate niche, where it should be placed in future editions.

While the book is nearly all its title claims for it, the addition of a few more chapters on plotting and computations would make it a comprehensive treatise on surveying, and we believe this expansion would prove advantageous to the author, since in its present shape it should be supplemented by personal instructions, or by other books which cover substantially the same ground.

Mechanically, the book is a good piece of work, and typographically attractive, but a little less ink on some of the cuts (pp. 131–132–302) would improve their appearance. The name and reputation of its author is sufficient to guarantee for its large sale, and these comments, it is hoped, may still further extend its usefulness in the near future. H.

The Practical Management of Dynamos and Motors. By Prof. Francis B. Crocker and Dr. Schuyler S. Wheeler. New York: D. Van Nostrand Company. 1892. Cloth, 5 x 7½. 32 pp. Price, $1.

The title of this book expresses clearly the characteristic purpose which the authors had in view. The subject-matter was prepared primarily to

assist those in charge of the installation and operation of dynamos and motors, by presenting the essential practical features of the work in clear and concise language, and by having the matter well classified and arranged for ready reference.

The general principles of dynamos and motors are treated briefly in the first two pages, and the remainder of the book is devoted to actual selection, installation, management, testing and general handling of these machines. In this respect this book is unique, and will be very useful to the practical man as well as the student.

Part I is devoted mainly to the essential considerations in selecting dynamos and motors and installing the same; methods of setting them up, making the electrical connections, placing fuses, switches, etc.; starting and stopping the machines, and instructions for running them, coupling them in parallel or series, etc.; and lastly, the testing of dynamos and motors, their adjustment, mechanical condition, electrical resistance, output and input, efficiency, magnetism, etc.

Part II treats of the localization and remedy of troubles in dynamos and motors, and includes the subjects of sparking at the commutator, heating of armature and field-magnets, bearings, noise, speed and failure of dynamo to generate or of motor to start, etc.

Throughout the book the heading of each paragraph is given in bold type, which aids greatly in reference. In Part II the subject of the localization and remedy of trouble is arranged and classified in a very convenient manner. Under each trouble the various causes are mentioned and under each cause the symptom by which it can be recognized and the remedy that should be applied. The words "Cause," "Symptom" and "Remedy" head their respective paragraphs, and are printed in bold type, and altogether this part of the book resembles a veritable *Materia Medica*.

The subject-matter of the book first appeared as a series of articles in the *Electrical Engineer*, of New York, between September, 1891, and May, 1892, and the demand for these articles led the authors to rewrite them for publication in the present form.

Anyone connected with the actual handling of these electrical machines or contemplating doing so, will find it extremely useful to have this little book by his side for reference and study, and students and electricians will find it a good investment as well. H. S. H.

The Alternate Current Transformer in Theory and Practice. By J. A. Fleming, M.A., D.Sc. (Lond.) Vol. II. *The Utilization of Induced Currents.* London: *The Electrician* Printing and Publishing Company, Limited. 1892. Cloth, 5¼ x 8½. 594 pp. Price, $5.

The first volume of this valuable book, which appeared in 1890, has become a standard work for study and reference and treated the general subject of induction of electric currents. The second volume, whose appearance has been anxiously awaited, takes up the utilization of induced currents, and, therefore, treats of the practical application and construction of transformers for the conversion and distribution of electrical energy.

The first chapter includes the historical development of the induction coil and transformer, from Henry's researches and Sturgeon's investigations to the present time, and contains many illustrations of early and recent apparatus and interesting results of experiments.

The second chapter goes into the distribution of electrical energy by transformers and explains the various systems and apparatus employed. The systems of Ganz, Westinghouse, Lowrie-Hall, Thomson-Houston, Mordey and Ferranti obviously receive the most attention. A number of plans and elevations of central stations and also switchboard diagrams are given for each system.

The next chapter takes up the general design and equipment of alternate current stations, and considers the boilers, engines, turbines, dynamos, etc., to be used, the selection of units, general arrangements, etc., and the conductors employed. Some attention is also given to the capacity effects, automatic change-over switches, pressure regulation, etc.

The fourth chapter enters into the construction and mode of action of transformers of the present day. The determination of the "transformer indicator diagrams," curves of electro-motive force, curves of magnetic induction and leakage, experiments on iron core losses, etc., are considered in the first part, and it is interesting to note that most of the methods and results described there are those of American investigators. The design of transformers is there treated in considerable detail and finally the various methods of measuring the efficiency of transformers are given.

The last chapter contains a brief description of electric welding and its applications, with illustrations of various welding tranformers, dynamos, etc.

Altogether, this book is the most complete treatment of the subject in print, and the second volume forms an important part of the whole, though it can be used to advantage as a separate volume, since it treats its particular part of the subject in so a complete manner.

Of course, being a pioneer book, there are a number of things that might be criticised, but they will doubtlsss be remedied in future editions. Typographical and other errors, so numerous in Vol. I, appear occasionally in Vol. II, and the typography and printing are equally poor, if not worse.

H. S. H.

Notes and Examples in Mechanics. With an Appendix on the Graphical Statics of Mechanism. By Irving P. Church, C.E. New York: John Wiley & Sons. 1892. Pp. 118 and 28, vi plates.

The author in his preface states that this forms a companion volume to his *Mechanics of Engineering*, but it could be well used in connection with almost any work on the subject; although one is surprised that so many deficiencies should have been found in the *Mechanics of Engineering*, which by the way is a volume of 800 pages.

The first chapter deals with a proper conception of forces, and while illustrating clearly what the author intends conveying does it in such a way that the conception is limited to forces exerted by or on rigid bodies, either at rest or in motion, and requires a recasting before it can apply to fluids in

motion. This chapter closes with an indirect derivation of Simpson's rule. Much less space is devoted to this rule in this and similar books than the subject deserves, and while, if properly used, it is one of the most useful tools the engineer has to work with, it is generally given scant room in our text-books, and its application is almost unknown. This rule gives approximate results in most cases, but in very many it gives exact values, and a reasonable knowledge of the method of using it and its limitations would require much less dependence on reference books for values of quantities in constant use among engineers.

Chapter II treats of the principles relating to non-concurring forces in a plane. In analyzing such forces the diagrams are not well selected. If a body is in equilibrium, any graphic representation of it should reasonably represent equilibrium. The author in his text covers the matter exactly, but the figure represents only two forces which could not possibly be in equilibrium, and it is really important that graphical representations, which are very valuable aids in securing lasting impressions should be so made that the conditions under discussion are accurately set forth.

The use of such terms as "heaviness" of a body, "anti-derivative" and "anti-resultant" are hardly necessary. They convey no meaning which cannot be conveyed in terms in general use. To many of the readers of this review an expression such as "a certain substance has a heaviness of forty," will mean absolutely nothing. The remainder of the chapter is devoted to an analysis of various combinations of rigid bodies at rest acted on by forces. The author calls attention again to the use of such phrases as "balanced forces," "forces in equilibrium," the meanings of which are perfectly clear, but which he thinks are unfortunately worded.

In Chapter III the author deals with the motion of a material point. His definition of acceleration is just as it should be, but his example is decidedly objectionable. He says, "similarly, if at the same instant, the acceleration of the material point is said to be twenty feet per 'square second' (or twenty feet per second, per second'), we mean," etc. The coining of a term as barbarous as "square second" is quite as bad as the using of many of the new terms which simply make one book harder to read than another, and while the author is not the originator of it, it should not be used by anyone, as the same thing can be better expressed otherwise.

It is a pity that space should have been given for the use of such terms as "speed" and "hurry," as units of velocity and acceleration.

The author states the general uselessness of the term momentum and how the use generally made of it to determine accelerating force is superfluous. Nevertheless, it is used by him in cases where the principle of the conservation of momentum is readily applicable. The balance of this chapter is taken up with problems relating to the pendulum in various forms.

Chapter IV is made up of numerical examples on the subjects previously treated of.

Chapter V treats of moment of inertia of plane figures.

The use of unusual terms is to be found here also—not unusual to students

of the author's other works—but to engineers and students generally; as for instance, "it will be noticed that the first term, $\frac{1}{12}$ *bt.*³ [or local (gravity) moment of inertia] . . . is very small as compared with the second, or 'transferral term' (*bt.* d^2), and '= 129,870,000 *bi.* fiftieths' or '20·77 *bi.* in."

Chapter VI treats of dynamics of a rigid body. Numerous examples are worked out, covering many special applications to machines for utilizing or absorbing energy.

Chapter VII treats of Mechanics of Materials and Graphical Statics, and covers such subjects as I-beams, treated without the use of moment of inertia, Lanza's tests of wooden posts, Pencoyd tests of columns, etc. The Appendix is devoted to notes on the Graphical Statics of Mechanism, and is interesting and valuable.

The volume as a whole is a very valuable one and any one interested in mechanics, who finds that he can follow the author, has a good working knowledge of the principles involved. H. W. S.

A Treatise on Gear Wheels. By George B. Grant. Published by the Author, 1893. Sixth Edition, pp. 103+2.

The fact that this little work is in its sixth edition, speaks strongly of the practical value of the matter contained therein. The reading-matter in the present edition is identical with that in the first edition and has the same defects as to arrangement and want of continuity due to its having been originally printed in a technical journal. The author has added two pages of index which will add greatly to its value as a work of reference.

H. W. S.

ANNUAL REPORT OF THE DIRECTOR OF THE DRAWING SCHOOL OF THE FRANKLIN INSTITUTE FOR THE SESSIONS 1892–93.

The work of the school has been very satisfactory this year, and stands pre-eminent in the department of mechanical drawing. The school adheres rigidly to its special technical lines, and does not profess nor attempt to be a school of art. Its object is to give the greatest amount of instruction that will be of the most value for constructive purposes, and to give this in the most efficient manner; that is to say, with the least consumption of time and money. In order to accomplish this, it has a clearly defined course, the result of years of experience and effort, which commences at the beginning and progresses regularly and logically to the end in view. That the methods employed have been well devised and selected, is shown by the number of young men who have entered this school with no previous knowledge of the subject, and who now hold responsible and valuable positions, due to the training received here, and to the development of tastes and qualifications for this useful and important line of work, which such training has caused.

The value of having a good knowledge of mechanical drawing, lies not merely in the possession of the ability to make such drawings in a manner

to be easily and clearly understood, but also in the ability to read and interpret them when made by others. Every mechanic should possess this knowledge, not merely superficially, but thoroughly. His usefulness is greatly increased by it, and his advancement made more certain and rapid. Many excellent workers, possessing superior skill of hand, physical endurance, good judgment, inventive faculties, quick decision, and influence with men, and who would make excellent foremen, have been kept at the bench all their lives, from lack of this knowledge. The number of draughtsmen required to plan and lay out the details of the world's constructive work is comparatively small, but the number of persons who should be able to read and understand these plans, should be limited only by the number of workers themselves, if the most economical results are to be obtained. In this connection, however, I have often observed that those individuals who attend the school, professedly for the purpose of not learning to make drawings, but merely to get a general idea, so as to be able to understand them, and who wish to skip all the elementary and theoretical parts and to go right into working drawings, rarely learn anything at all, simply wasting their time in getting a misconception of what they are doing. The very best way to obtain facility in understanding drawings, is to learn how to make them, and the time and work required to do this are well spent, even if the student never makes another after leaving the school.

The instruction in free-hand drawing is carried on as an adjunct to the constructive drawing, and is intended for an initiation and training in the shape and decoration of constructive details, and not as an introduction to the fine arts.

The instruction in architectural drawing is confined to the plain, every-day requirements of those engaged in building, and does not include a study of the various orders and periods of architecture. It does not profess to educate architects of public buildings, mausoleums and temples, but merely to be of use to the carpenters, plumbers and builders engaged in ordinary work.

As regards the efficiency of the school, the fact should be known, that, although the pupils obtain this useful and important knowledge at a merely nominal charge, yet this is accomplished at no expense to the public at large, and costs the Franklin Institute only the rental of the class rooms.

The Senior Mechanical Class is in charge of Mr. Lucien E. Picolet, the Intermediate Mechanical Classes are in charge of Messrs. George S. Cullen and William H. Sheahan, the Junior Mechanical Classes are in charge of Messrs. George W. Irons and H. Allen Higgins, and the Architectural Class is in charge of Mr. Clement Remington.

The following students are entitled to Honorable Mention:

In the Senior Mechanical Class.

Charles Kolb, Charles McLoughry,
Edward G. Budd, Christian Hagenlocher,
George W. Hassellund, Oscar Mowry,
Eric Ostram.

In the Intermediate Classes.

Emil Snyder,
William Wilkinson,
William C. Gehring,
Zenas Whitemore,
William W. B. Stamm,
Charles Shorb,
William E. Riess,
Samuel R. Preston,
Harry Mehary.

In the Junior Mechanical Classes.

H. P. Rhoads,
Joseph Doebrich,
Miss S. D. Blackwell,
Walter H. Spencer,
George Young,
Rodney Davis,
Roy H. Stacks.

In the Architectural Class.

Benjamin H. Barton,
Jackson Dunlap,
E. D. Salter,
Joseph Sargeant,
Andrew Sauer.

In the Free-Hand Class.

Fritz Ullberg,
H. J. Vollmer,
Norman B. Wheeler.

The following students are awarded scholarships from the B. H. Bartol Fund, entitling them to tickets for the next term, beginning September 19th:

Edward G. Budd,
William Wilkinson,
Emil Snyder,
Benjamin H. Barton,
William C. Gehring,
George Young,
H. P. Rhoads,
Fritz Ullberg.

The following students, having attended a full course of four terms, with satisfactory results, are awarded certificates to that effect:

August Hoffman,
William L. Ambler,
John A. Megenedy,
Charles F. X. Smith,
Malcolm Lovett,
Oscar Mowry,
Joseph Pfluger,
Christian Hagenlocher,
Arthur Bentley,
Austin H. Riegner,
Narciso Battle,
Eric Ostram,
Benjamin H. Barton,
Albert Schoell,
James Patterson,
Howard R. Lamborn,
George Gramlick,
James Walton.

The organization and methods of this School of Constructive Drawing have reached a high degree of excellence, but no pains will be spared to improve them wherever possible in the future, and to maintain our leading position in this line. WILLIAM H. THORNE, *Director.*

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, May 17, 1893.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, May 17, 1893

JOSEPH M. WILSON, President, in the chair.

Present, fifty-one members and four visitors.

Additions to membership since last report, seven.

The Actuary reported several resolutions adopted by the Board of Managers at its stated meeting, held May 10th inst., recommending to the Institute that the annual fee from contributing members be raised from $5 to $8; that the annual payment of second-class stockholders be raised from $3 to $6; that the fee for life membership be raised from $50 to $100; and submitting certain changes in the existing by-laws to conform to the foregoing recommendations.

The President directed that the resolutions be posted on the bulletin board in accordance with the by-law pertaining to amendments, in order that the subject might be considered at the next following stated meeting.

The Secretary reported the following action of the Committee on Library, taken at its stated meeting of May 1st inst., viz:

"The Committee on the Library respectfully presents to the Institute a minute upon the death of Mr. Frederick Ransome, which occurred in London, April 19, 1893.

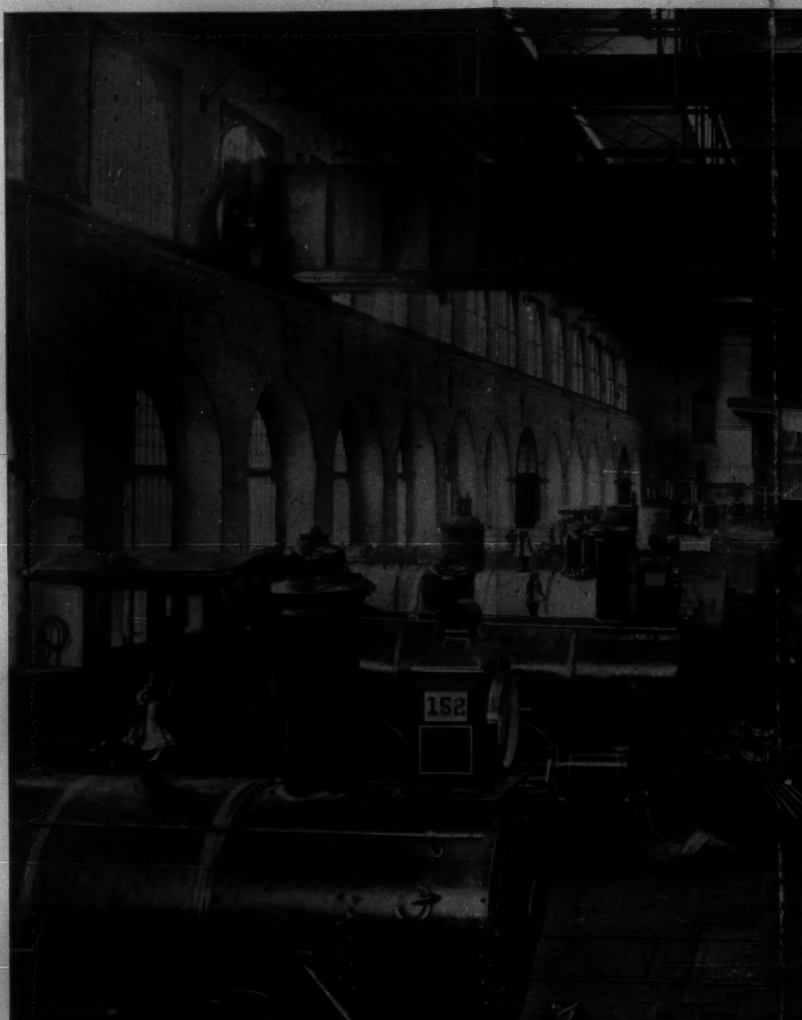
"For many years Mr. Ransome has acted as agent of the committee in London, and as early as September 19, 1877, in recognition of his valuable services, he was elected by the Institute an honorary member, upon the nomination of the Board of Managers.

"Since that time Mr. Ransome has continued his gratuitous services as purchasing agent of the committee, and he has been particularly useful in enabling the committee to complete the collections of various British scientific periodicals by searching out and securing missing back numbers. This service requires continued waiting and watching, and by this labor of love Mr. Ransome aided in completing thirty-one British journals, whose publication began early in the century and still continues.

"Mr. Ransome's services in relation to the publications of the British Patent Office were also extremely valuable.

"The committee desires to place this minute on the records of the Institute, expressing its sense of the loss sustained by the Institute in the death of Mr. Ransome, and it desires also to add the expression of its profound sorrow at the event."

On motion of Mr. Henry R. Heyl, the communication of the committee was ordered to be spread upon the minutes of this meeting.



100-TON HIGH-SPEED ELECTRIC TRAVELING CRANE INSTALLED IN THE NEW ERECTI
INCORPORATED, PHILADELPHIA, PA. [Span of bridge, 74 ft. 8 in.; length of run-way
minute; trolley travel, crosswise, 50 and 100 ft. per minute; hoisting and lowering, 5,

ERECTING SHOPS OF THE BALDWIN LOCOMOTIVE WORKS. MADE BY WM. SELLERS & CO., un-way, 335 ft.; speeds (under absolute control) as follows: bridge travel, 100 and 200 ft. per ing, 5, 10, 20 and 40 ft. per minute.]

The Secretary reported a vacancy in the Committee on Science and the Arts caused by the resignation of Mr. S. Lloyd Wiegand. Prof. L. F. Rondinella was elected to fill the vacancy.

Mr. Geo. G. Rockwood, of New York, read a paper on "Photo-ceramics," describing a process of his invention for permanently fixing photographic impressions in colors upon glass. The paper was illustrated by the exhibition of specimens of the new art, which elicited many expressions of admiration. The thanks of the meeting were voted to Mr. Rockwood for his interesting communication. (The paper has been referred for publication.)

Mr. Julius F. Sachse presented a paper descriptive of an improvement in tele-photo lenses devised by Mr. Albert B. Parvin, of Philadelphia. The paper was illustrated by the exhibition of specimens of photographic work executed with the improved lens. (Referred for publication.)

Mr. Robt. B. Haines, Jr., exhibited a number of specimens of his automatic micrometer rolling-mill gauge for measuring hot plates, sheets and bars while in process of rolling. The apparatus shown by Mr. Haines exhibited certain improvements upon the original form of the device shown at the stated meeting of November, 1892. The speaker also made some critical remarks upon the new standard gauge for sheets and plates approved at the last session of Congress.

Under new business, Mr. George V. Cresson was elected as a Trustee of the Elliott Cresson Medal Fund in place of Mr. Samuel Sartain.

The Secretary, in his monthly report, referred to the interesting results obtained by M. Moissan, in recent experiments on the behavior of metallic oxides when subjected to the extremely high temperatures attainable in the electric furnace. He exhibited an interesting product made in a furnace of this kind and which is at present attracting considerable attention on account of its properties as an abrasive material. This product is made by subjecting an intimate mixture of carbon and ground silica for a number of hours to the heat of the electric furnace, the resulting product when freed from intermingled impurities being affirmed to be a compound of carbon and silicon in atomic proportions, corresponding to the formula CSi. This product is crystalline in texture and is extremely hard. It is crushed to powder of various degrees of fineness, and either in the powder form or formed into discs, with a suitable cementing material is used as a substitute for diamond dust, corundum and emery. It is known by the trade name of carborundum.

The Secretary exhibited a specimen of chased aluminum, which had been very successfully electroplated with silver by a process devised by Mr. J. D. Darling, of Philadelphia.

Adjourned.

WM. H. WAHL, *Secretary.*